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A COMPARISON OF CROP YIELDS USING
EL NINO AND NON-EL NINO
CLIMATOLOGICAL DATA
IN A CROP MODEL

by

Kenneth J. DeMoyse

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A Comparison of Crop Yields Using El Nino and Non-El Nino
Climatological Data In a Crop Model

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EL NINO AND NON-EL NINO
CLIMATOLOGICAL DATA
IN A CROP MODEL

by

Kenneth J. DeMoyse

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Soil Science and Biometeorology

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Ken DeMoyse

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ABSTRACT

A Comparison of Crop Yields Using El Nino
and Non-El Nino Climatological Data
in a Crop Model

by

Kenneth J. DeMoyse, Master of Science

Utah State University, 1990

Major Professor: Dr. Gail E. Bingham
Department: Plant, Soils, and Biometeorology

During a 38-year period (1950-1987), daily climatological data for the five largest corn-producing states in the Midwest (Illinois, Indiana, Iowa, Nebraska, and Minnesota) were averaged to obtain climatological data sets for both El Nino and non-El Nino years. These data bases were then used in the crop yield model, CERES Maize, to determine if the El Nino climate resulted in any differences in yield for each state.

After running the model with the two data sets for the five different states, the results showed no significant difference in the simulated corn yields between El Nino and non-El Nino years.

(104 pages)

INTRODUCTION

The periodic warming of the normally cold waters off the coast of Peru is called "El Nino" (also known as El Nino-Southern Oscillation and hereafter referred to as ENSO). This phenomenon has been documented by ice cores (Thompson and Mosley-Thompson, 1986), alluvial flood deposits (Wells, 1986; Craig and Shimada, 1986), beach ridges (Sandweiss, 1986), and fossil mollusks (DeVries, 1986) to have existed along the Peruvian coast for at least several millenia (Nicholls, 1989). Quinn et al. (1978) presents a detailed chronology of ENSO events beginning in 1541. These events affect the interannual fluctuations of the climate over much of the globe (Rasmusson and Carpenter, 1982, 1983; Ropelewski and Halpert, 1986, 1987). The weather anomalies associated with these events range from droughts in areas that usually have seasonal monsoon rains (Ropelewski and Halpert, 1987) to flooding in arid regions to extremely severe and numerous hurricanes and typhoons to above- and below-average temperatures in various parts of the world. More importantly, they bring warmer than usual ocean water to the South American coast, where there is normally an upwelling of cold water. This warming of the ocean waters causes the food cycle of the area to be severely disrupted. The natural food chain (plankton-cardines-seabirds-etc.) is upset, causing economic chaos in the area (Cane and Zebiak, 1986).

Even though the exact cause or causes for the initiation of an ENSO event are still not known, we do know enough about its formation to be able to detect its onset during the early stages of development, usually 6 to 9 months before it reaches the coast of the Americas (Cane and Zebiak, 1986).

Initially, it was the hope of this research project that advance knowledge of an upcoming ENSO event could be used to give corn producers a better idea of how their corn yields might be modified by expected differences in precipitation and temperatures resulting from an ENSO event. Corn was used in this project because it is a very important cash crop in the Midwest. If it could be shown that yields during an ENSO are a certain percentage above or below normal, the farmers could take appropriate steps when alerted that an ENSO was imminent. Depending on how production was affected, these steps could mean adding additional acreage if the yields were improved, or planning additional expenditures for irrigation and fertilizer to help improve yields if it were shown that they decrease during ENSO periods.

If it could be shown that ENSO events indeed affect the climatology of our largest Midwestern corn-producing states (Illinois, Indiana, Iowa, Nebraska, and Minnesota) and their subsequent crop yields, then perhaps this knowledge could be applied to other crops in other parts of the world as well.

OBJECTIVES

The main objective of this project was to compare the results of a crop yield model using ENSO and non-ENSO climatological data sets for the five largest midwestern corn-producing states (Figure 1) to see if the modelled yields differ significantly. If so, it would mean that the climatological conditions during an ENSO event are different than those deemed normal (derived from non-ENSO years), and this may help to explain some of the dramatic peaks and valleys observed in smoothed crop yields over the past 38 years (Figures 2a-f).

To achieve this objective, two tasks first had to be accomplished. The first was to examine the sea surface temperatures of the Pacific Ocean. Averaging them over time and space allowed the determination of a set of years representing the ENSO events between 1950 and 1987. This period was chosen because of the availability of a comprehensive data base for both sea surface temperatures and daily climatic observations. This set of ENSO years was then used to compare climatic parameters and crop yields.

The second task was to compile a climatic data base for both ENSO and non-ENSO years from the daily weather records of all reporting stations in each state for the past 38 years. The overall averages of precipitation and temperature maximums and minimums of these years (after

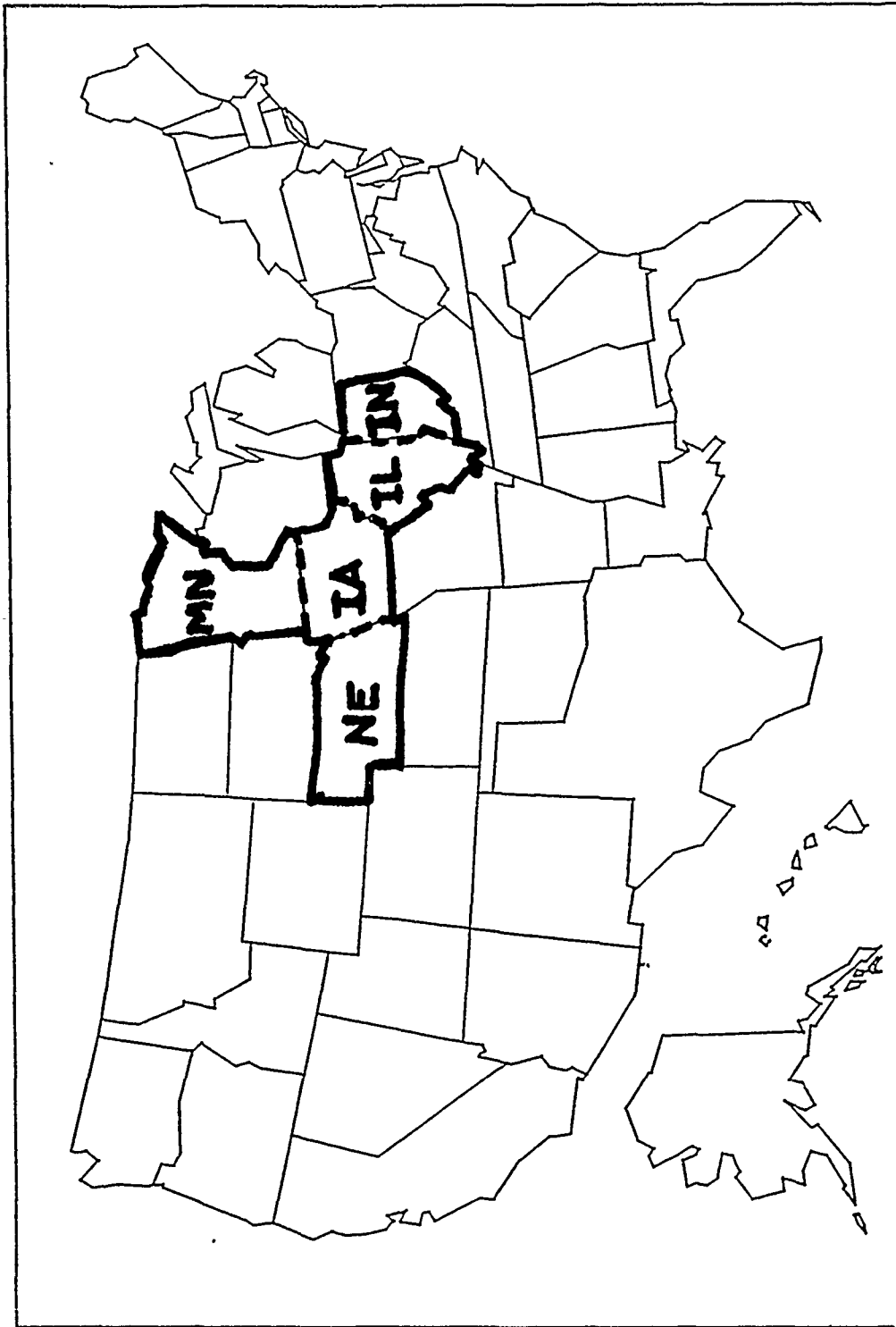
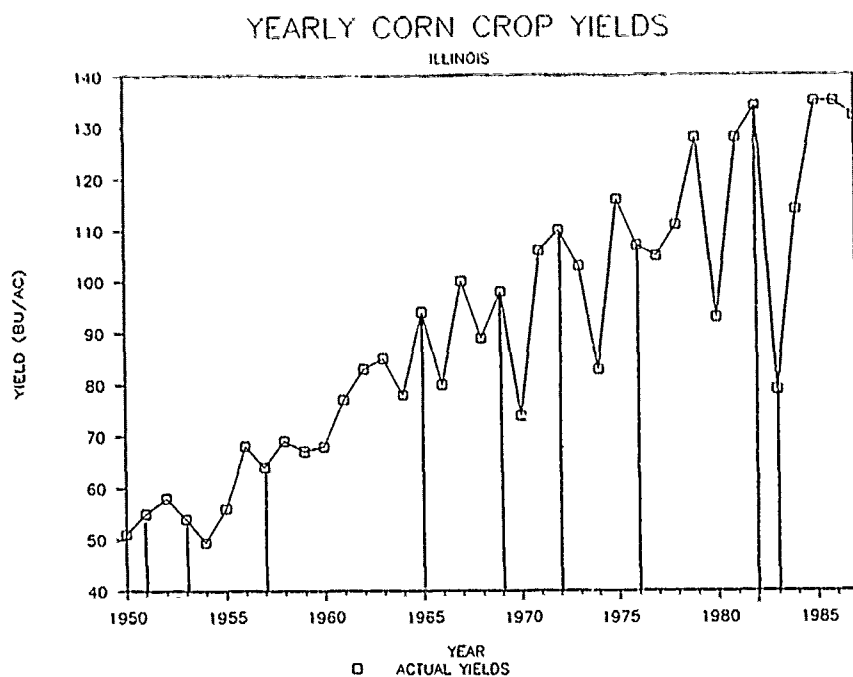


Figure 1. Five midwestern states of interest.

a. Illinois



b. Indiana

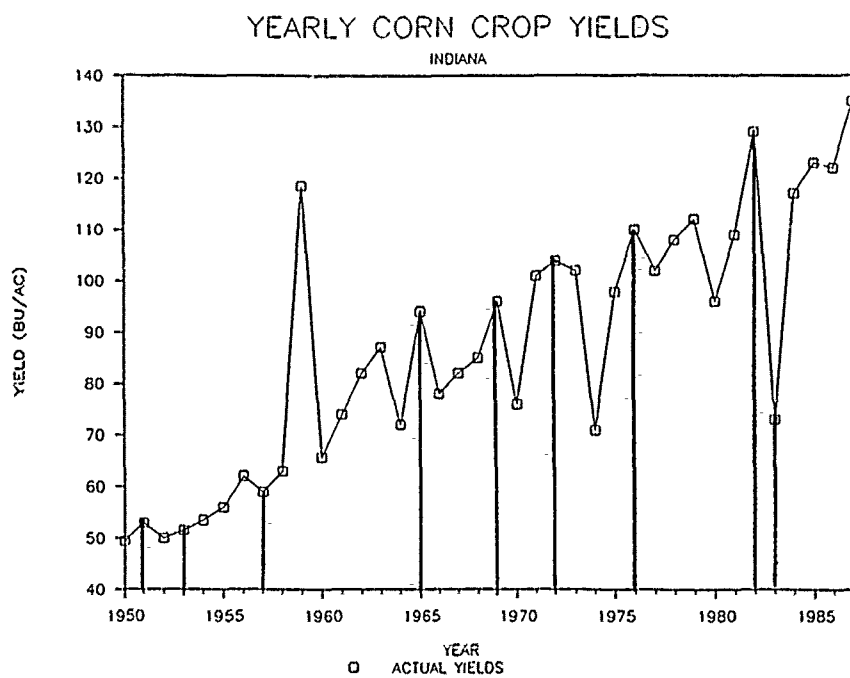
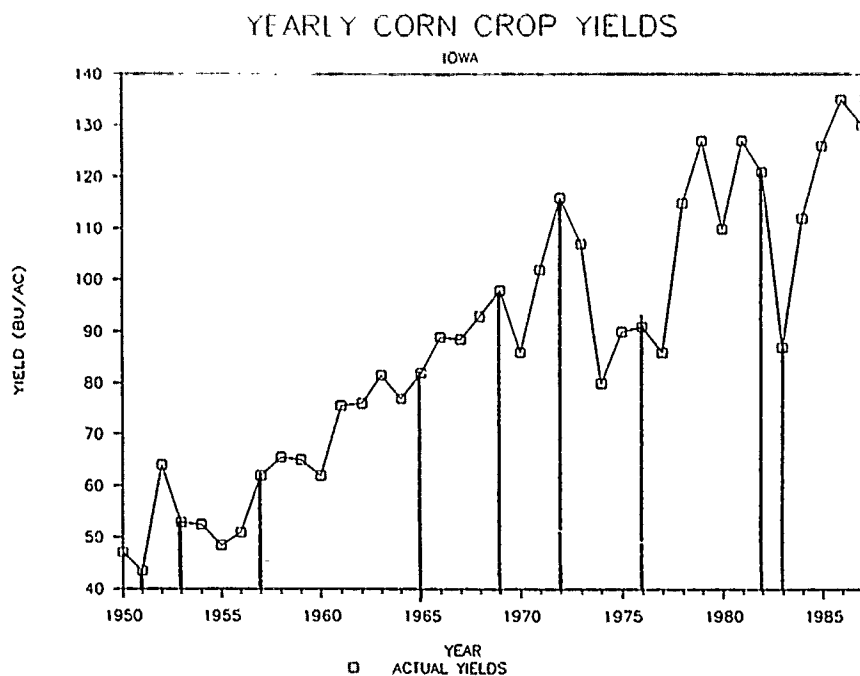


Figure 2. Average corn crop yields (1950-1987).
Dark lines represent El Nino events.

c. Iowa



d. Minnesota

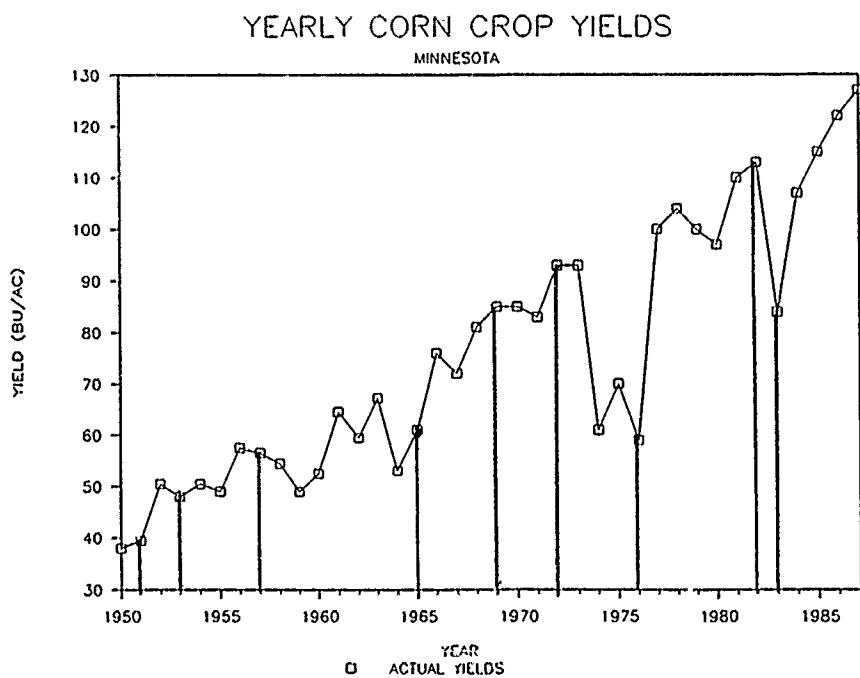
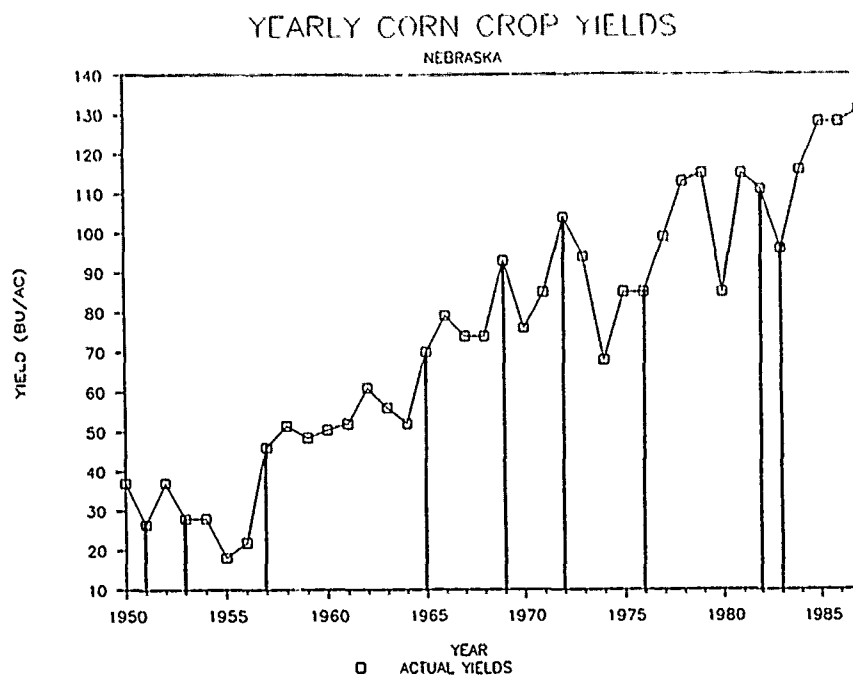


Figure 2. (continued)

e. Nebraska



f. U. S. Average

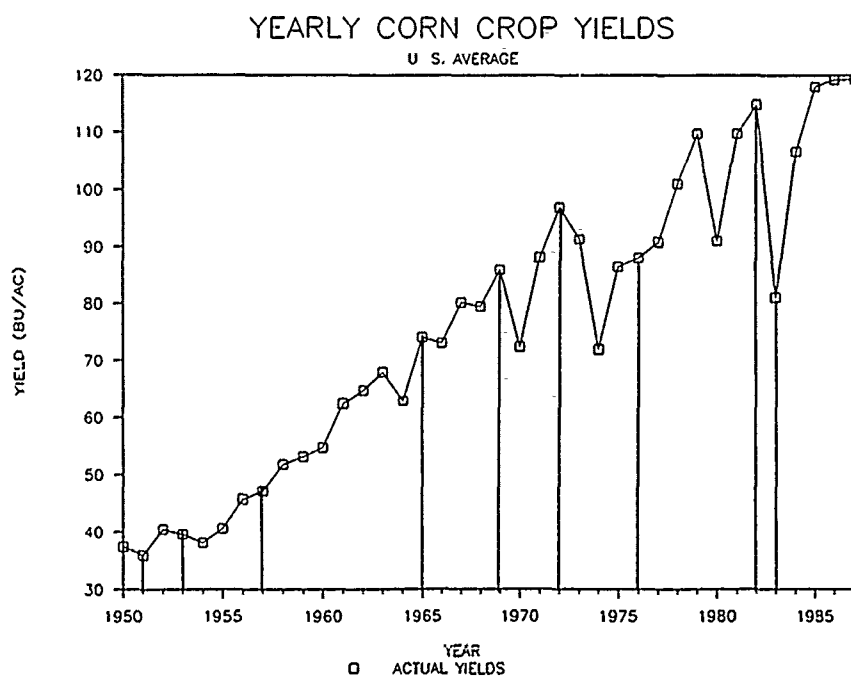


Figure 2. (continued)

separating them into ENSO and non-ENSO years) formed the composite climatic data sets for each state and was used in running the crop yield models.

Once these two tasks were accomplished, the overall objective was achieved by running the crop yield model using both the ENSO and non-ENSO data sets and comparing the resultant yields. If these yields differ significantly, then one might infer that the climatology of that region during ENSO periods is sufficiently different to affect agricultural production.

REVIEW OF LITERATURE

El Nino

In his book, El Nino, La Nina, and the Southern Oscillation, S. George Philander (1990) quotes Senor Dr. Luis Carranza, 1891 president of the Lima, Peru, Geographical Society, stating that a countercurrent flowing from north to south had been observed between the ports of Paita and Pacasmayo. The sailors had named the current "El Nino" (the child Jesus) because it has been observed to appear right after Christmas. Dr. Carranza goes on to explain that when the countercurrent is observed, the whole weather pattern of the region is altered. Normally barren deserts are deluged with heavy rains and exceptionally warm temperatures, and the normally abundant bird and marine life of the area disappears. This reference to El Nino is one of the earliest on record as to its location and its consequences.

It wasn't until 1969 that J. Bjerknes associated the El Nino with the Southern Oscillation discovered by Sir Gilbert Walker in 1923. These events all seem correlated to major changes in rainfall patterns and wind fields over the tropical Pacific and Indian oceans and with temperature fluctuations in southeastern Africa, southwestern Canada, and the southeastern United States.

El Nino is the phase of the Southern Oscillation when the trade winds are weakened; there is low pressure over the

eastern Pacific and high pressure over the western tropical Pacific. The normal east-to-west trade winds weaken, slack off, and then reverse direction. The result is a weakening of the Walker Circulation, and the warmer, western Pacific waters begin to flow eastward. As the waters reach the eastern edge of the ocean, they overwhelm the normally cold, nutrient-rich waters upwelled off the coast of South America. This weakening of Walker Circulation allows the convective zone of rainfall that usually exists in the extreme western Pacific to move eastward, changing the pattern of the monsoon rains in that part of the world.

Several authors (Rasmusson and Wallace, 1983; Horel et al, 1986; Berlage, 1966; Horel and Wallace, 1981; Namias, 1969; Dickson and Namias, 1976) have shown that during an ENSO event, the Hadley Circulation strengthens with the appearance of upper-level easterly wind anomalies near the equator. On the poleward flanks, the subtropical jet streams are intensified and displaced equatorward (especially during November, December, and January). The resultant impact on the weather regimes in the Americas is severe wind and rain storms that occur along the coast of California, heavy snows that fall in the mountains of the western United States, and extremely heavy rains that fall in Brazil, Paraguay, and northern Argentina. Although the correlation is not extremely high, the authors do show some correspondence between ENSO events and the severe winter (summer) weather found in the western U.S. (South America).

It is this teleconnection and its effect on the climate of the midwestern portion of the U. S. that was explored in this project.

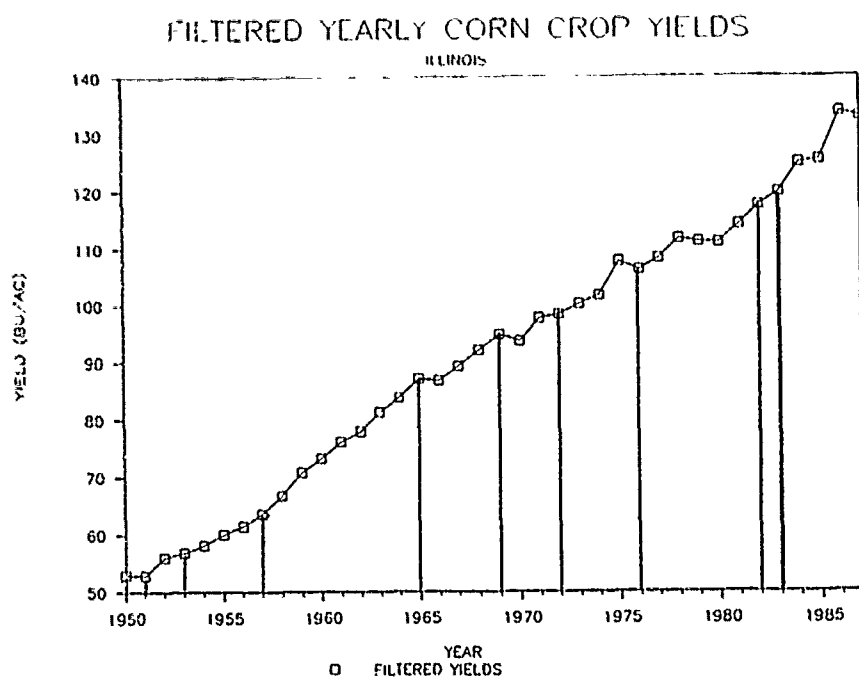
Corn Yield Predictions

As shown in Figures 2a-f and 3a-f, the crop yield over the past 38 years shows tremendous variability, even after using a 9-year smoothing technique on the values (Kogan, 1987). These figures show this variability and the impressive increase in yield due to technological advancements over the 38-year period.

Over the past few decades, management of some of the major factors influencing crop production (soil fertility, insect and weed pressure, and crop genetics) has improved. However, the effect of the most uncontrollable factor in crop production, weather, and its interactions with other factors has not changed and has not even been carefully investigated (Andresen et al, 1987). Two of the most important climatic factors--precipitation and temperature (maximum and minimum)--are examined here for their roles in estimating crop yields (Andresen et al, 1987; Carlson and Gage, 1987; Liverman et al, 1986; Skaggs and Baker, 1985). Changnon et al. (1989) shows that increasing rainfall by as much as 25 percent has a positive effect on crop yields when all other climatic conditions are near normal. During other times, increased rainfall tends to decrease yield.

Rosenzweig (1989) shows that temperature is the single

a. Illinois



b. Indiana

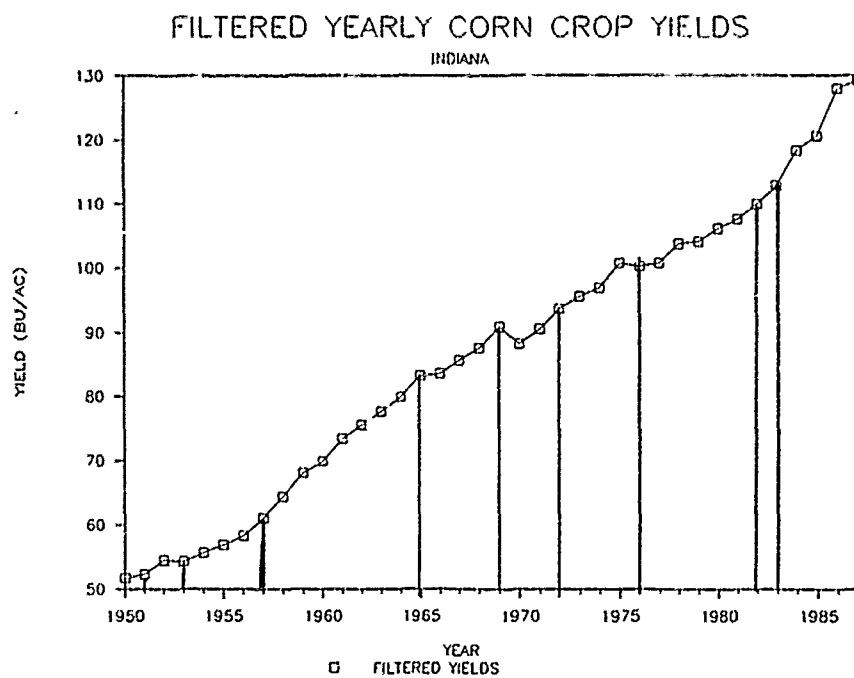
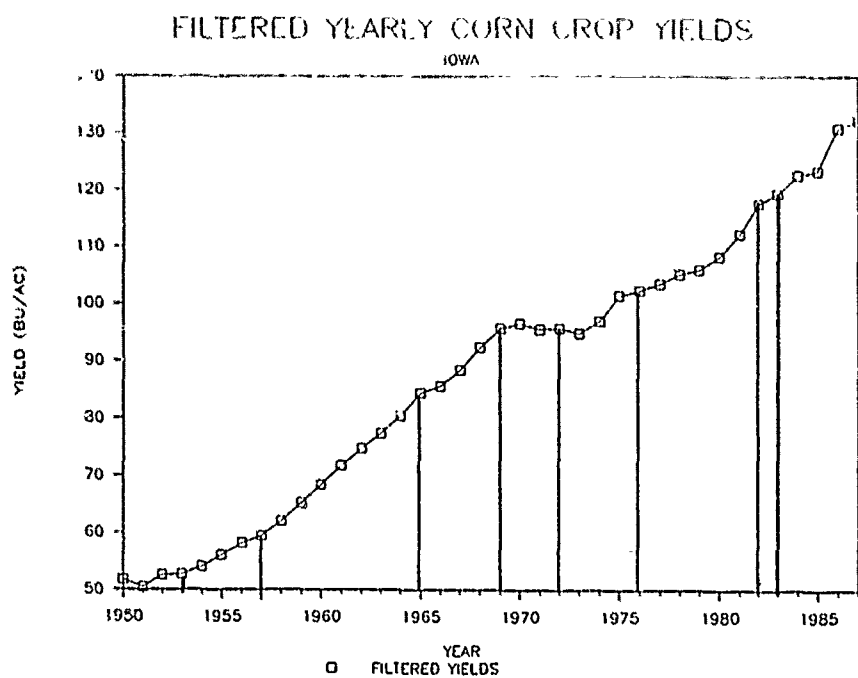


Figure 3. Average corn crop yields after a 9-year smoothing technique (1950-1987). Dark lines represent El Niño events.

c. Iowa



d. Minnesota

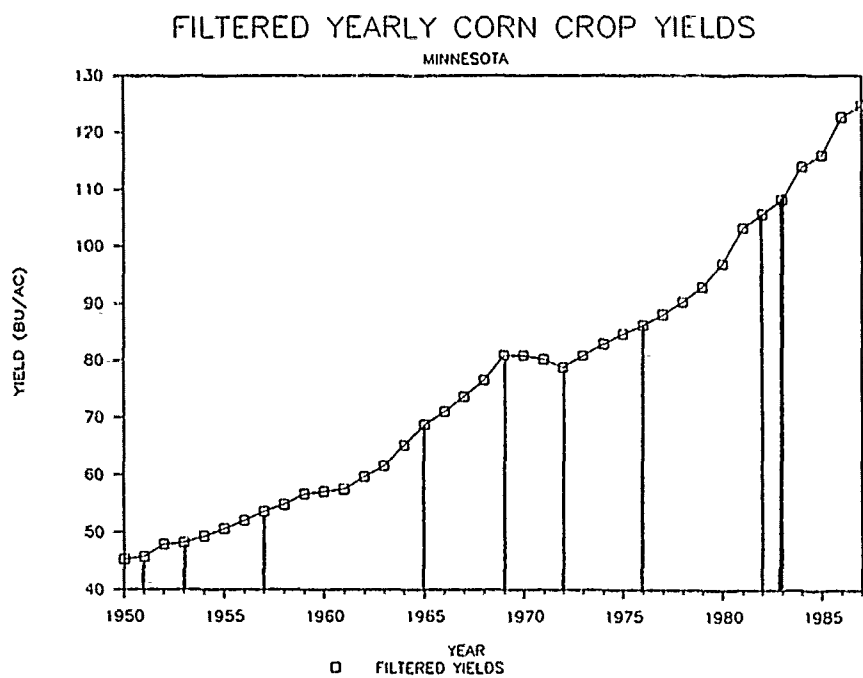
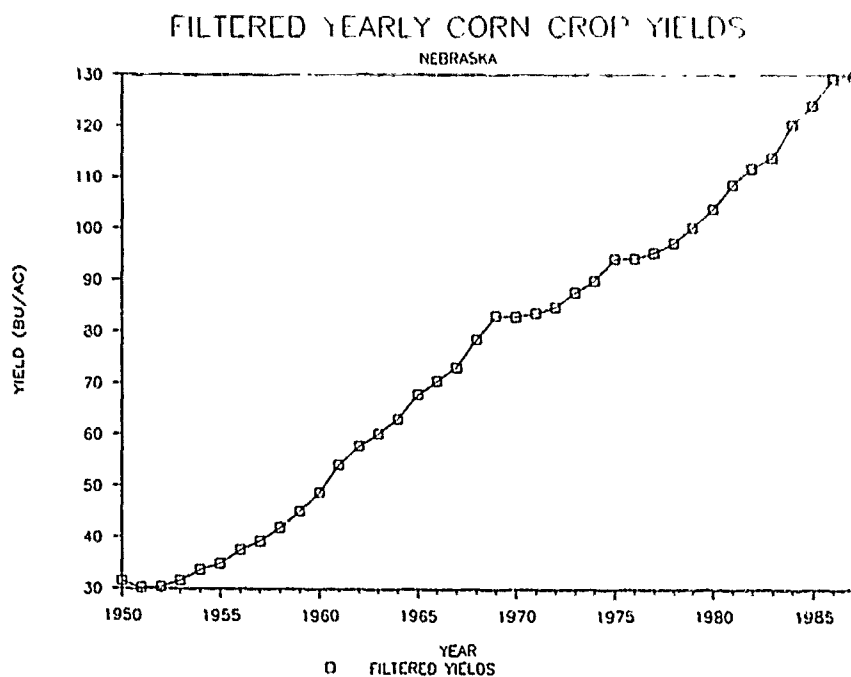


Figure 3. (continued)

e. Nebraska



f. U. S. Average

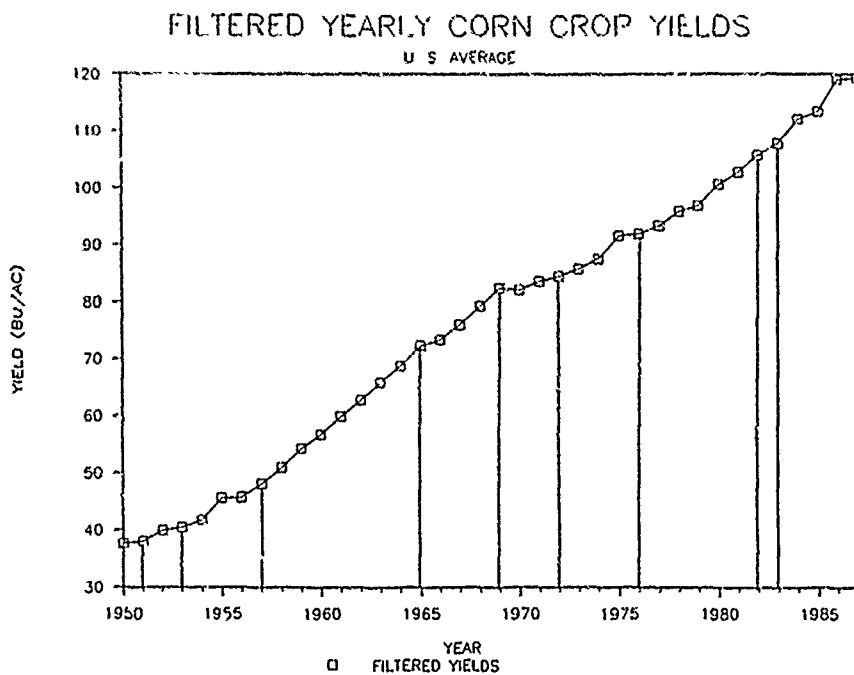


Figure 3. (continued)

most important factor in determining increases or decreases in yields. It is especially critical in terms of stress degree days (Sdd=number of days where the maximum temperature is above 90° F) during the silking period (10 July through 20 August). The more Sdds during this period, the lower the yield (Newman and Scheeringa, 1985). Although it has not been shown that ENSO events cause average temperatures to rise or fall, we can expect the yields to follow the results of climatological averages.

Attempts have been made to tie corn crop yields to volcanic eruptions and increased aerosols. Handler and O'Neill (1987) tried to prove that increased aerosols (due to low-latitude [$<30^{\circ}\text{N/S}$] volcanic eruptions) reduce solar radiation, which in turn is responsible for an increase in the corn yields. The problem with their logic is that most crop yield models show decreasing yields with decreasing solar radiation values. They also use the growing season yields immediately after an eruption (i.e., April 1982 eruption and 1982 yield data) to prove their theory, when it would probably take 6-12 months for the aerosols to spread poleward in the stratosphere sufficiently to reduce incoming radiation in the corn-growing regions.

Still, it has been shown that changes in precipitation and temperature have an effect on both actual and modelled results. It is hoped that the climatic changes in the midwestern states (if any) will be shown to lead to these same yield changes.

PROCEDURE

Determination of El Nino Years

A set of sea-surface temperatures (SSTs) and temperature anomalies for the Pacific Ocean was obtained from the Scripps Oceanographic Institution for the period of 1950 to the present. This data set gives the average monthly temperatures (and deviations from the mean) for 5° grid points in the Pacific Ocean. This data was averaged for the nine values found within the El Nino box (Figure 4): 0° to 10° S by 80° to 90° W (Flueck and Brown, 1987); the values are presented in Appendix B. These monthly averages were then grouped by frequency to determine the median and percentile levels. Based on the fact that moderate to strong ENSO events had SSTs averaged within the El Nino box that fell outside the 88th percentile (Flueck and Brown, 1987), the median was calculated to be 22.0° C and the 88th percentile began at 23.4° C. Using these criteria, the following eight years were picked as moderate to strong ENSO events: 1951, 1953, 1957, 1965, 1969, 1972, 1976, and 1982-83 (Figure 5). The moderate to severe events were chosen so that their effects (if any) on the climatology of the region would be more pronounced and more easily demonstrated. Although most authors don't agree on the same ENSO events due to the manner in which they are chosen (i.e., sea-level pressure differences between Darwin and Tahiti, sea-surface temperatures, vulcanism, etc.), the ENSO set chosen for this

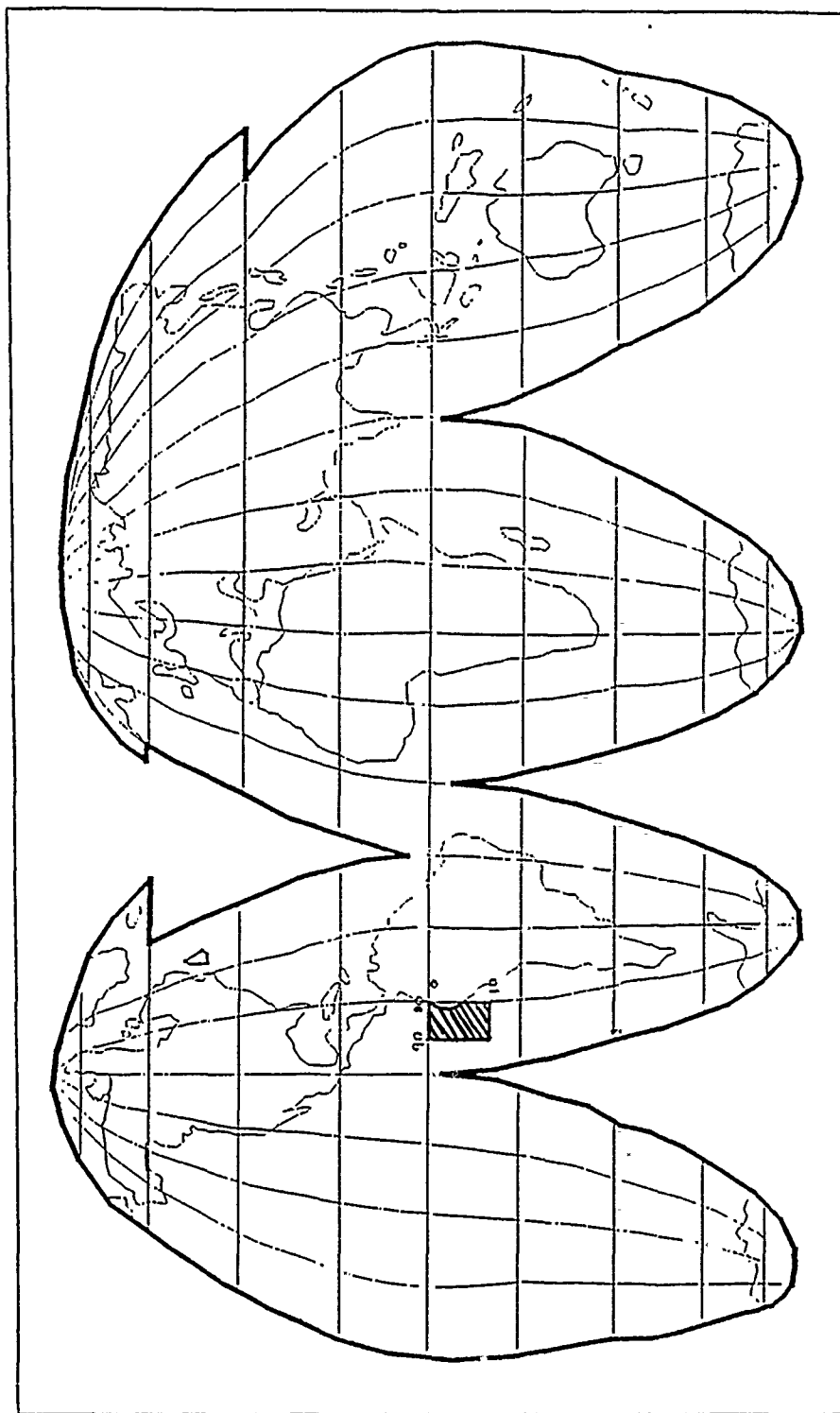


Figure 4. Map of the El Nino Box. 0 - 10° S by 80 - 90° W.

AVERAGE SEA-SURFACE TEMPERATURES

0-10 S BY 80-90 W

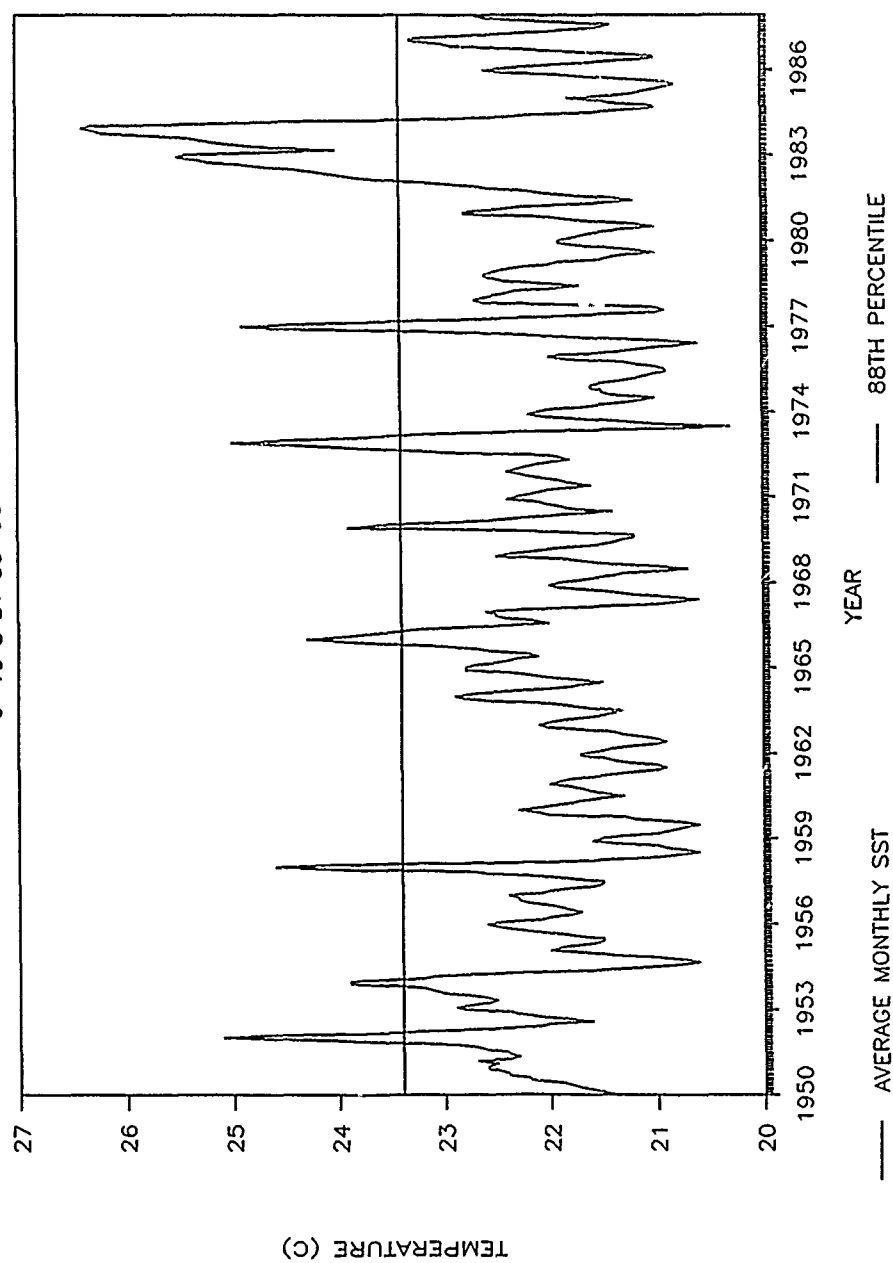


Figure 5. Average Sea-Surface Temperatures. Averaged over the El Nino box by month ($^{\circ}$ C).

TABLE 1. Various sets of El Ninos determined by various authors

AUTHOR	YEAR																
	51	52	53	57	63	65	66	67	68	69	72	76	78	79	82	83	86
Quinn et al. (1978)	X		X	X		X				X	X	X			X	X	
Rasmusson and Carpenter (1982)	X		X	X	X	X				X	X						
Flueck and Brown (1987)	X			X							X	X			X	X	
Rogers (1987)			X	X	X	X				X	X	X	X				
Schreiber and Schreiber (1987)				X	X						X				X	X	
Handler (1984)	X	X			X		X	X	X		X			X	X		X
DeMoyse (1990)	X		X	X		X				X	X	X			X	X	

project is in fairly good agreement with others (Table 1). It should also be noted that even though the 88th percentile was chosen as the demarcation line for moderate and stronger ENSO events based on Flueck and Brown's work, a slight change in the percentile rank used would not make any difference in the years chosen.

Once an ENSO set was determined, the growing season immediately following it (called ENSO+1) was used as the year in which crop yields and climatic variables were examined to make up the "ENSO" set.

Climatic Composite Construction

The daily weather records of the reporting stations in

each of the five states for the period of 1950 through 1987 were obtained from the Department of the Air Force, OL-A, Environmental Technical Applications Center (ETAC), Asheville, N. C. Depending on the state, the year, and the variable being examined, the total number of these reporting stations varied from a low of 86 (minimum temperatures/Indiana) to a high of 253 (precipitation/Nebraska). These variables were averaged (precipitation, maximum and minimum temperatures) by day and by year for each state. From this record, the eight ENSO periods were averaged together to form an ENSO climatological data set for each state. The remaining 30 years were then averaged together to form the non-ENSO climatological data set for each state.

Examination of Climatic Values

Before these data files were used in the crop models, the Palmer Drought Severity Index (PDSI) for each year and each region of the states was examined to see if there was any apparent correlation between ENSO+1 years and drought. The PDSI was prepared using the Moisture Anomaly Review System (MARS) available from the National Climatic Data Center, Asheville, N. C. The results were mixed; some of the ENSO+1 years showed evidence of being in a drought situation while other ENSO+1 years showed no indication of a drought. These inconsistent results were found in all regions and in all five states (Appendix F).

The monthly averages for each variable were then calculated for each state for both ENSO and non-ENSO years to see if they were significantly different. Using a t-test with a significance level of 95 percent, the means of the ENSO years were compared to the means of the non-ENSO years. Out of the 125 possible cases (5 months times 5 states times 3 variables), only one case showed a statistically significant difference between ENSO and non-ENSO years. This was found in the averages for Indiana/Precipitation/May. Generally speaking however, no difference was shown between the mean values for the variables in ENSO years and those of non-ENSO years.

The Model

The crop yield model, CERES Maize, was used for estimating crop yields in this project. It was developed at the University of Hawaii in conjunction with Michigan State University, the International Fertilizer Development Center, Muscle Shoals, Alabama, and the International Benchmark Sites Network for Agrotechnology Transfer. The model, which has been thoroughly documented (Jones and Kiniry, 1986) and widely tested (Singh, 1985), simulates crop responses to major factors that affect crop yields: climate, soils, and management. It employs simplified functions to predict the phenological development; apical development related to morphogenesis of vegetative and reproductive structures; extension growth of leaves and stems; senescence of leaves;

biomass production and partitioning; root system dynamics; and the effects of soil-water deficit on the photosynthesis and photosynthate partitioning in the plant.

Model Input

Once the averaged daily precipitation and temperature values were obtained for each state, data files were created for each of the states to be used in the crop yield model. The CERES Maize model required daily precipitation, maximum and minimum temperatures, and solar radiation values as input. Precipitation and temperature values came from the climatological data bases; the solar radiation values were calculated using the tables of solar radiation at the earth's surface (Jensen, 1973) and the equation

$$R_s = (0.35 + 0.61S) R_{so}$$

where R_s is the solar radiation value needed in the crop model, S is the ratio of actual to possible sunshine, and R_{so} is the solar incident on the earth's surface on cloudless days. Through experimentation with the model, the value for S was set at .07 to simulate the increased cloudiness due to the fact that the composite climatological sets have some precipitation occurring every day.

In addition to precipitation, solar radiation values, and temperatures, a representative latitude for each state was entered into the data file as well. This value was later used by the model for calculations of evapotranspiration and growth phases.

Model Use

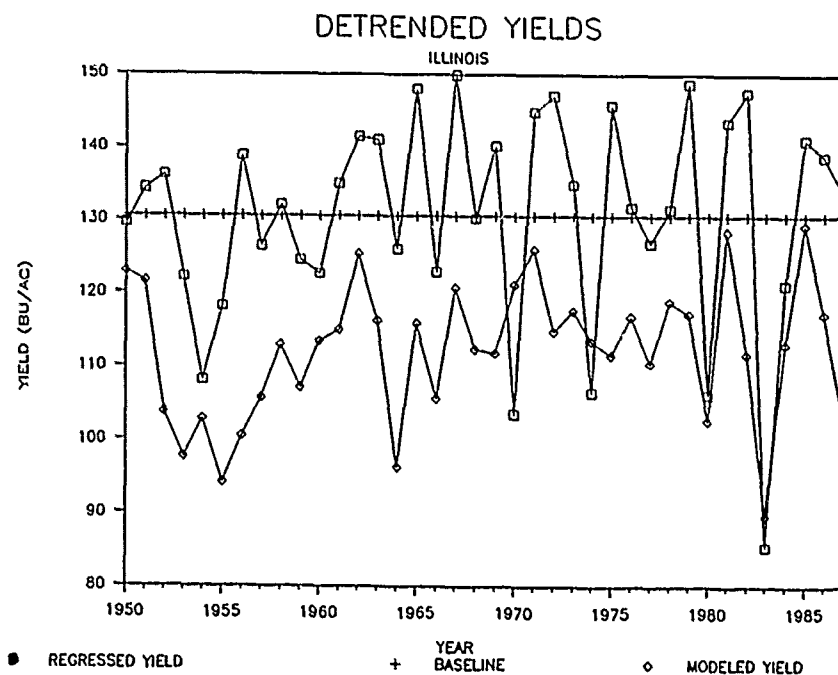
Before running the crop model with the composite climatological data sets, the model had to be initialized with certain variable values specifically for the Midwest. The program requires the initial planting date, set to May 15 for all states. There is also an option to change the soil type and crop variety; these were set to medium texture silt loam (Terjung et al., 1984) and CP170 (a variety that fills fast and is sensitive to the changes in the photoperiod) (Terjung et al., 1984). The program was set for rainfed only (no irrigation), and all runs had adequate fertilization at the start and were fertilized twice during the growing cycle (see Appendix E for a sample printout of a model run).

The model was then validated by obtaining estimated yields using the averaged monthly climatic data for each year in each state. These results were later used for comparison with the yields obtained using the composite climatic data sets to determine if the differences were statistically significant at the 95th percentile level.

Determination of Significance

To test the ENSO and non-ENSO yield results for a significant difference, the significance level had to first be decided upon (95%), and the model had to be run through all the years and all the states to obtain an average and standard deviation that could then be used for comparison

a. Illinois



b. Indiana

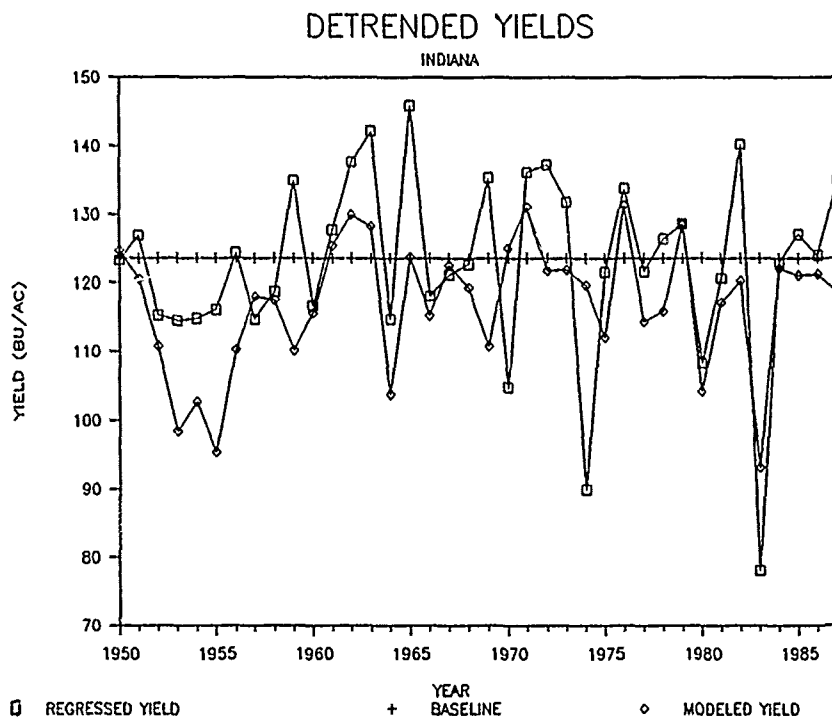
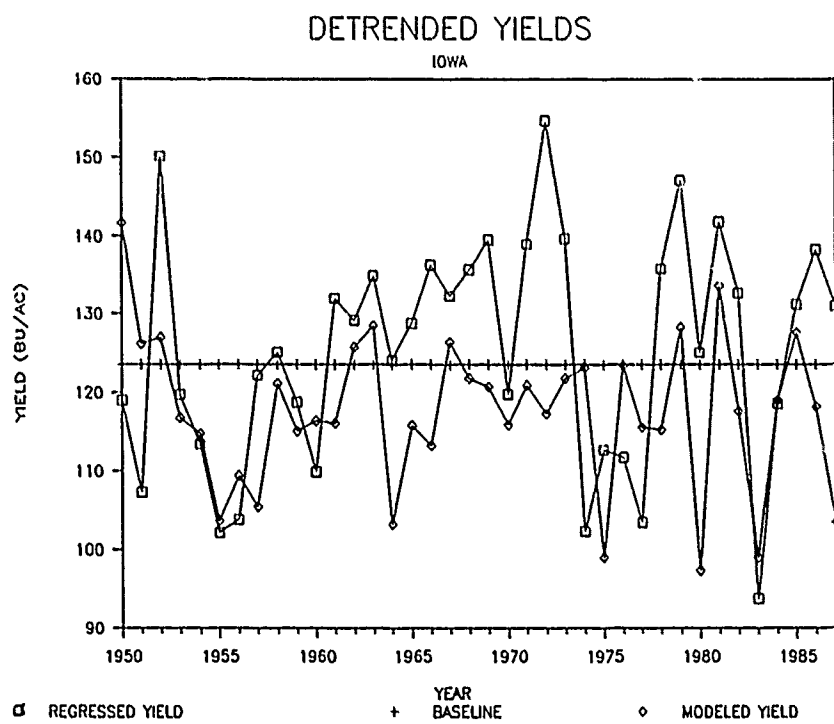


Figure 6. Detrended yields. Actual yields by state after being detrended using a regression equation and setting the previous values against a baseline. Modelled results are also given for purposes of comparison.

c. Iowa



d. Minnesota

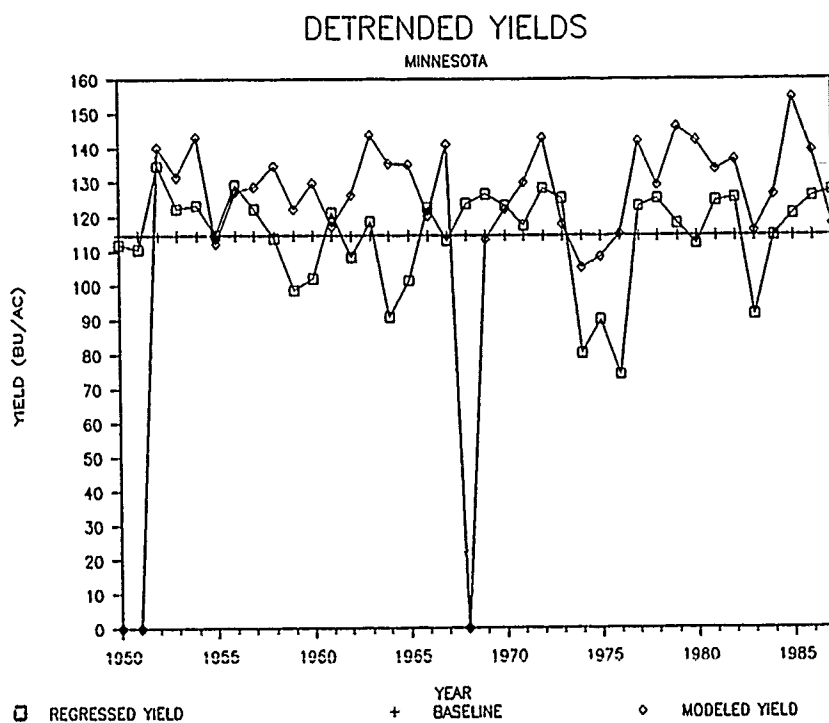


Figure 6. (continued)

e. Nebraska

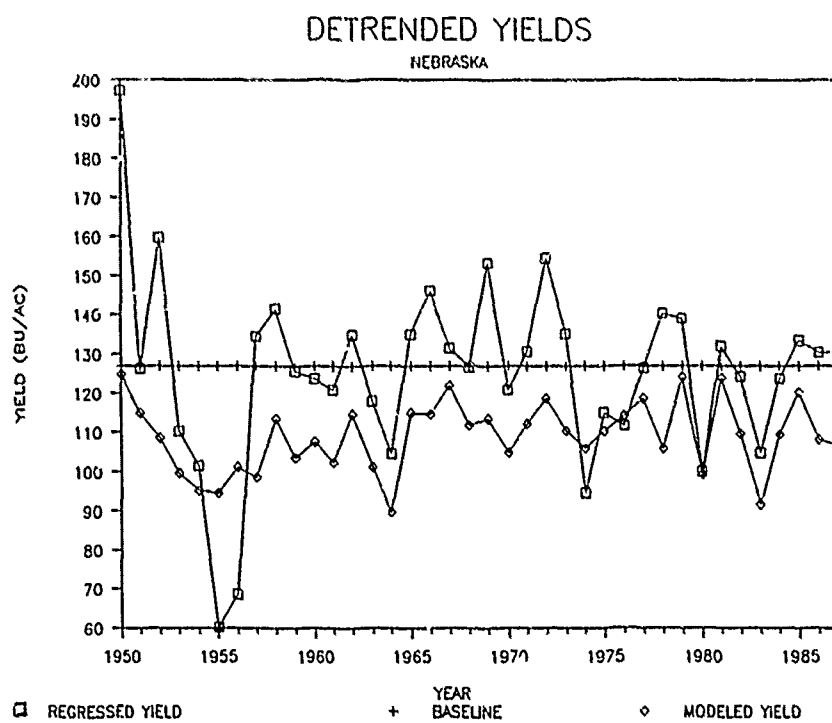


Figure 6. (continued)

purposes. To do this, the yields of each state were first smoothed out using the 9-year smoothing technique (Figures 3a-f). These yields were then run through a regression model to get a regression equation. Since this line removed most of the variability due to weather and left in the increasing trend due to technological advancements, the yields had to be detrended using a baseline value obtained for 1987. The actual yields were then adjusted against this baseline and the regression equation (Figures 6a-e). Once these new detrended values were determined, they were grouped together according to whether they were an ENSO or a non-ENSO year and averaged. Using a 95 percentile significance level, a confidence interval was computed for each state for the actual non-ENSO yields. The ENSO yields determined from the composite climatological data sets were then compared to see if they fell within the 95th percentile C. I.

RESULTS

After testing the weather parameters obtained from averaging the two separate groups, comparing their means for statistical differences, and finding none, it was no surprise when the crop yield results using the CERES Maize model showed little difference between ENSO and non-ENSO years for each of the states. Table 2 shows the yields per state and the percent difference from non-ENSO years as compared to ENSO years.

Table 2. Model yield results and differences

<u>STATE</u>	<u>NON-ENSO YEARS</u>	<u>ENSO YEARS</u>	<u>% DIFFERENCE</u>
Illinois	110.3 bu/ac	110.4 bu/ac	+0.091%
Indiana	116.6	114.8	-1.568%
Iowa	116.5	118.8	+1.936%
Minnesota	142.4	139.7	-1.933%
Nebraska	121.4	108.3	-12.096%

The only state that showed something of a difference was Nebraska. These yields are predicted based on a composite climatological data base in which there was precipitation every day, and the temperatures did not show any of the extremes that naturally occur. The abnormally high yields in Minnesota could also be accounted for by the fact that the growing season in the model had to be extended to allow for maturity of the corn. This allowed the model to predict unusually high yields for an area that doesn't normally achieve these. Even though the expected yields themselves

should be looked at with some suspicion, the differences between the two sets of data are valid and were shown to exist. Even when the solar radiation values were increased and the yields became unreasonable, the percent difference between the two sets of data for each of the states remained about the same. Another interesting result is the fact that the sign of the difference did not stay the same for the five states.

The differences between the two modeled yields were then compared to the standard deviations found in each state using the actual weather data and yields. As expected, there was no significant difference (at the 95% level) found between the expected yields using ENSO climatology and the yields using non-ENSO climatology.

CONCLUSIONS

While it was originally hoped that some of the dramatic yearly differences might result from the effect of El Ninos on the climate and the subsequent yields, it immediately became apparent that yields in the year directly after an ENSO event did not coincide with either the peaks or the valleys in the history of crop yields (Figures 1a-f).

This was further evidenced by the fact that even though temperature and precipitation have a direct impact on crop growth and yield, the compiled climatological data bases for both ENSO and non-ENSO years showed no real statistical difference between the values for ENSO and non-ENSO years in any of the variables in any of the states, with the exception of only one case. When these climatological parameters were inserted into the crop yield models, the resultant yields should not have shown any major differences between the different data sets. Even though not significant, the 12 percent difference between ENSO and non-ENSO yields for Nebraska, when the monthly averages showed no significant difference, may have resulted from the fact that the model uses daily values in the input; even though the monthly averages were very close, the daily values that went into that average may have been different enough at different times of the growing season to yield this difference. This sensitivity of the model to daily changes in temperatures and precipitation is something that was

expected despite the small difference between the averaged climatic inputs.

Stated another way, Nebraska may indeed exhibit a climatic difference, but further investigation and more years of data are needed to support this outcome. While there was no significant difference between the monthly means for precipitation and maximum and minimum temperatures for Nebraska at the 95 percent level, during a number of months the various variables came very close to being significantly different. This may have had a cumulative effect in the crop model, resulting in the yield difference.

The overall conclusion is that ENSO events are not associated with any significant impacts on the climatological parameters investigated in this study. The climatological data bases do not show any significant difference between ENSO and non-ENSO years, and the results from a crop yield model confirm this lack of yield-affecting difference.

RECOMMENDATIONS FOR FURTHER STUDY

A number of areas are indicated where further study may uncover connections between the ENSO events and changes in crop yield, among them to:

- investigate only those states that seem to have their jet stream altered during an ENSO event.
- extend the period of investigation.
- examine the yield responses of other crops.
- assemble a composite climatic base more representative of the actual weather.

Jet Stream Alteration

Examining the weather maps for the Midwest (or any other area of interest), can indicate the normal upper-level flow of air. By comparing this pattern to one established during ENSO events, areas can be chosen that show an upper-level flow changed during the ENSO. The nature of the change may mean cooler than normal temperatures (if troughing develops), warmer than normal temperatures (if high pressure builds up and ridging occurs), more or less persistent rain, or a change in the timing of delivery of the precipitation (convective storms giving large amounts all at once versus stable, cumuloform rain). These changes in the weather pattern may have a noticeable impact on crop yields.

Period of Investigation

Because this study traced data back to 1950, only eight moderate to strong ENSO events were chosen. If the period of investigation were extended to the turn of the century (or longer), more ENSO events could be used to develop the climatic data base and also to develop the non-ENSO data base. Using a period of 80-100 years would give about 20-25 ENSO events, which in turn could give a very representative climatic base.

Other Crops

This study only looked at corn; other crops (like wheat, soybean, or alfalfa), might show some correlation between the minor climate changes during an ENSO period and the yields given by these crops. Other crops may prove to be more sensitive to subtle changes in the temperature and precipitation than corn; if this is the case, then maybe their expected yields would show the difference between ENSO years and non-ENSO years.

More Representative Climatic Base

Due to the way this data base was constructed, precipitation was found to occur every day, even though amounts were small, this is not what happens in nature. Although partly accounted for by not using irrigation and by using a constant solar value for each entire month, periods of drought or excessive rain may exist in either the ENSO or non-ENSO years that are lost in the composite data base.

The composite also reduces periods of extreme cold and hot weather due to its averaging. These periods may have extreme impact on overall yields and need to be examined.

REFERENCES CITED

- Andresen, J.A., R.F. Dale, J.J. Flether, and P.V. P. 1987. Prediction of corn yields using an energy-crop index for counties in Indiana. pp. 231-233. In Proc. the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology, W. Lafayette, IN. 15-18 September 1987.
- Berlage, H.P. 1966. The Southern Oscillation and world weather. K. Ned. Meteorol. Inst. Meded. Verh. 88:1-152.
- Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. Mon. Wea. Rev. 97:163-172.
- Cane, M., and S. Zebiak. 1986. El Nino prediction from Columbia University scientists. Bull. Amer. Meteor. Soc. 67:580-581.
- Carlson, J.D., and S.H. Gage. 1987. Quantitative relationships between crop phenology, insect pest phenology, and temperature for field corn in Michigan. pp. 259-262. In Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology, W. Lafayette, IN. 15-18 September 1987.
- Changnon, S.A., S. Hollinger, and P. Garcia. 1989. Analyzing the effects of additional rainfall on corn and soybean yields. pp. 41-45. In Proc. from the 19th Conf. Agric. and Forest Meteor. and 9th Conf. Biometeor. and Aerobiology, Charleston, SC. 7-10 March 1989.
- Craig, A.K., and I. Shimada. 1986. El Nino flood deposits at Batan Grande, Northern Peru. Geoarchaeology 1:29-38.
- Demoyse, K.J. 1990. A comparison of crop yields using El Nino and non-El Nino climatological data in a crop model. M.S. thesis. Utah State University, Logan.
- DeVries, T.J. 1986. Fossil evidence for an early Pleistocene origin of El Nino off Peru. pp. 27-31. In Proc. of the Chapman Conf. on El Nino, Guayaquil, Ecuador. 22-29 October 1986.
- Dickson, R.R., and J. Namias. 1976. North American influences on the circulation and climate of the North Atlantic sector. Mon. Wea. Rev. 104:1255-1265.
- Flueck, J.A., and T.J. Brown. 1987. A new approach to identification and prediction of "El Nino" events. Trop. Ocean-Atmos. Newslett. 37:2-4.

Handler, P. 1984. Possible association of stratospheric aerosols and El Nino type events. *Geophys. Res. Lett.* 11:1121-1124.

Handler, P., and B. O'Neill. 1987. Volcanic aerosols, El Nino events, Indian monsoons, tropical cyclones and U. S. corn yields. pp. 512-515. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology*, W. Lafayette, IN. 15-18 September 1987.

Horel, J.D., and J.M. Wallace. 1981. Planetary-scale atmospheric phenomena associated with the Southern Oscillation. *Mon. Wea. Rev.* 109:813-829.

Horel, J.D., V.E. Kousky, and M.T. Kagano. 1986. Atmospheric conditions in the Atlantic sector during 1983 and 1984. *Nature* 322:248-251.

Jensen, M.E. 1973. *Consumptive use of water and irrigation water requirements*. 1st ed. American Society of Civil Engineers, N. Y., N. Y.

Jones, C.A., and J.R. Kiniry. 1986. *CERES-Maize: A simulation model of maize growth and development*. 1st ed. Texas A&M Press, College Station, TX.

Kogan, F.N. 1987. Evolution of weather impact on yield variability. pp. 239-240. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Confer. Biometeor. and Aerobiology*, W. Lafayette, IN. 15-18 September 1987.

Liverman, D.M., W.H. Terjung, J.T. Hayes, and L.O. Mearns. 1986. Climatic change and grain corn yields in the North American Great Plains. *Climatic Change* 9:327-347.

Namias, J. 1969. Seasonal interaction between the North Pacific Ocean and the atmosphere during the 1960's. *Mon. Wea. Rev.* 97:173-192.

Newman, J.E., and K.L. Scheeringa. 1985. Seasonal weather impacts on Indiana corn fields, 1980-1984. pp. 270-280. In *Proc. of the 17th Conf. Agric. and Forest Meteor. and 7th Conf. Biometeor. and Aerobiology*, Scottsdale, AZ. 21-24 May 1985.

Nicholls, N. 1989. How old is ENSO? *Climatic Change* 14: 111-115.

Philander, S.G.H. 1990. *El Nino, La Nina, and the Southern Oscillation*. 1st ed. Academic Press, Inc., San Diego, CA.

Quinn, W.H., D.O. Zopf, K.S. Short, and R.T.W.K. Yang. 1978. Historical trends and statistics of the Southern Oscillation, El Nino, and Indonesian droughts. Fish. Bull. 76:663-678.

Rasmusson, E.M., and T.H. Carpenter. 1982. Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Nino. Mon. Wea. Rev. 110:354-384.

Rasmusson, E.M., and T.H. Carpenter. 1983. The relationship between Eastern Equatorial Pacific sea surface temperatures over India and Sri Lanka. Mon. Wea. Rev. 111:517-528.

Rasmusson, E.M., and J.M. Wallace. 1983. Meteorological aspects of the El Nino/Southern Oscillation. Science 222: 1195-1202.

Rogers, J.C. 1987. Variability in clouds and precipitation over South America and the Tropical Atlantic associated with the Southern Oscillation. Trop. Ocean-Atmos. Newslett. 37:7-10.

Ropelewski, C.F., and M.S. Halpert. 1986. North American precipitation and temperature patterns associated with the El Nino/Southern Oscillation (ENSO). Mon. Wea. Rev. 114: 2352-2362.

Ropelewski, C.F., and M.S. Halpert. 1987. Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation. Mon. Wea. Rev. 115:1606-1626.

Rosenzweig, C. 1989. Climate change and CO₂ effects on wheat and corn in the Great Plains. pp. 26-29. In Proc. from the 19th Conf. Agric. and Forest Meteor. and 9th Conf. Biometeor. and Aerobiology, Charleston, SC. 7-10 March 1989.

Sandweiss, D.H. 1986. The beach ridges at Santa, Peru: El Nino, uplift, and prehistory. Geoarchaeology 1:17-28.

Schreiber, R.W., and E.A. Schreiber. 1987. Equatorial seabirds and El Nino: Close encounters in a marine system. Trop. Ocean-Atmos. Newslett. 37:14-15.

Singh, U. 1985. A crop growth model for predicting corn (Zea mays L.) performance in the tropics. Ph.D. diss. University of Hawaii, Honolulu.

Skaggs, R.H., and D.G. Baker. 1985. Fluctuations in the length of the growing season in Minnesota. Climatic Change 7:403-414.

Terjung, W.H., J.T. Hayes, P.A. O'Rourke, and P.E. Todhunter. 1984. Yield responses of crops to changes in environment and management practices: Model sensitivity analysis. I. Maize. Int. J. Biometeor. 28:261-278.

Thompson, L.G., and E. Mosley-Thompson. 1986. Assessment of 1500 years of climate variability and potential of long term record of ENSO events from Andean glaciers. pp. 112-114. In Proc. of the Chapman Conf. on El Nino, Guayaquil, Ecuador. 27-31 October 1986.

Wells, L.F. 1986. An alluvial record of El Nino events from Northern coastal Peru. pp. 68-69. In Proc. from the Chapman Conf. on El Nino, Guayaquil, Ecuador. 27-31 October 1986.

APPENDICES

Appendix A. Pascal Program Used to Average SSTs.

The monthly values for the grid points within the El Nino box were read off the sea-surface temperature data reels and averaged together to obtain a monthly value for that area.

```
(
  Program to read Blendedsst.dat file
  and get averages by long. and lat.
  I = lat, J = long.
)

PROGRAM BSST (INPUT,OUTPUT);

CONST
  N = 91;
  M = 180;

VAR
  SST           : REAL;
  iflag         : string[255];
  IDA,IMO,IYR,IY : INTEGER;
  I,J,K,COUNTER : INTEGER;
  SUM,AVG       : REAL;
  file_in       : string[30];
  file_out      : string[30];
  IN_FILE       : TEXT;
  OUT_FILE      : TEXT;

BEGIN
  (
    Open files
  )
  write ('Enter Input Filename --> ');
  readln (file_in);
  ASSIGN(IN_FILE,file_in);
  RESET (IN_FILE);
  write ('Enter Output Filename --> ');
  readln (file_out);
  ASSIGN (OUT_FILE,file_out);
  REWRITE(OUT_FILE);

  (
    START READING FILE
  )
  WHILE NOT EOF(IN_FILE) DO
    BEGIN
      READLN(IN_FILE,IDA,IMO,IYR,IY);
      WRITELN (IDA,' ',IMO,' ',IYR,' ',IY);
      WRITELN(OUT_FILE,IDA,' ',IMO,' ',IYR,' ',IY);
      COUNTER := 1;
      SUM := 0.0;
      FOR I := 1 TO 91 DO
        BEGIN
          FOR J := 1 TO 180 DO
            BEGIN
              READ(IN_FILE,SST);
              SUM := SUM + SST;
```

```
END;  
AVG := SUM / 180.0;  
WRITELN (OUT_FILE,I,' ',AVG);  
WRITELN ('*****',I);  
END;  
FOR I := 1 TO 206 DO  
begin  
  READLN(IN_FILE,iflag);  
  WRITELN(iflag);  
end;  
end;  
CLOSE(IN_FILE);  
END.
```

Appendix B. Averaged Sea-Surface
Temperatures (SSTs) for the
El Nino Box. (0-10S by 80-90W) ($^{\circ}$ C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN
1950	21.4	21.5	21.6	21.7	21.8	21.9
1951	22.6	22.5	22.7	22.4	22.3	22.4
1952	25.1	24.8	23.6	23.1	22.4	22.1
1953	22.8	22.9	22.7	22.6	22.5	22.6
1954	23.9	23.2	23.1	22.7	22.0	21.5
1955	21.6	22.0	21.9	21.8	21.6	21.5
1956	22.6	22.4	22.1	22.0	21.8	21.7
1957	22.4	22.1	22.0	21.8	21.6	21.5
1958	24.6	24.0	22.0	21.5	21.0	20.8
1959	21.5	21.3	21.0	20.9	20.8	20.7
1960	22.3	22.1	22.0	21.8	21.7	21.5
1961	21.9	21.8	21.6	21.4	21.2	21.0
1962	21.7	21.5	21.4	21.2	21.0	20.9
1963	22.1	22.0	21.9	21.7	21.5	21.4
1964	22.9	22.7	22.5	22.1	21.8	21.7
1965	22.8	22.7	22.5	22.4	22.3	22.1
1966	24.3	24.0	23.8	23.5	23.3	23.0
1967	22.6	22.1	21.5	21.0	20.8	20.6
1968	21.9	21.7	21.6	21.4	21.3	21.0
1969	22.4	22.2	22.0	21.8	21.5	21.4
1970	23.6	23.0	22.6	22.3	22.0	21.7
1971	22.3	22.2	22.1	22.0	21.8	21.6
1972	22.3	22.2	22.1	22.0	21.8	21.9
1973	24.5	24.0	23.5	23.0	22.0	21.0
1974	22.1	22.0	21.7	21.5	21.3	21.1
1975	21.5	21.3	21.2	21.1	21.0	20.9
1976	21.9	21.4	21.2	21.0	20.8	20.6
1977	24.9	24.2	23.6	22.7	22.0	21.5
1978	22.6	22.5	22.4	22.3	22.0	21.7
1979	22.4	22.2	22.0	21.9	21.5	21.4
1980	21.9	21.8	21.7	21.6	21.4	21.3
1981	22.8	22.5	22.3	22.0	21.5	21.2
1982	23.0	23.4	23.7	23.9	24.1	24.2
1983	25.4	24.8	24.0	24.6	24.9	25.1
1984	26.3	25.3	24.5	23.0	22.4	22.1
1985	21.8	21.4	21.2	21.1	21.0	20.9
1986	22.6	22.3	22.0	21.7	21.3	21.0
1987	23.5	23.3	23.0	22.5	22.0	21.8

<u>YEAR</u>	<u>JUL</u>	<u>AUG</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>
1950	22.2	22.2	22.4	22.4	22.5	22.6
1951	22.4	22.6	22.7	22.9	23.5	24.1
1952	22.0	21.6	21.8	22.1	22.3	22.4
1953	22.8	23.0	23.1	23.2	23.4	23.9
1954	21.0	20.8	20.6	20.7	21.0	21.4
1955	21.5	21.7	21.9	22.2	22.4	22.5
1956	21.8	21.9	22.0	22.2	22.3	22.3
1957	21.5	21.8	22.0	22.5	22.8	24.0
1958	20.6	20.7	20.9	21.0	21.4	21.6
1959	20.6	20.8	21.2	21.3	22.0	22.1
1960	21.3	21.5	21.6	21.7	21.8	22.0
1961	20.9	21.0	21.3	21.4	21.5	21.7
1962	21.0	21.1	21.3	21.4	21.7	22.0
1963	21.3	21.6	21.8	22.0	22.5	22.8
1964	21.5	21.7	22.0	22.2	22.4	22.8
1965	22.2	22.5	22.7	23.0	23.5	23.9
1966	22.4	22.0	22.1	22.4	22.5	22.5
1967	20.9	21.2	21.4	21.6	21.9	22.0
1968	20.7	21.0	21.5	21.6	21.9	22.5
1969	21.3	21.2	21.2	21.8	22.6	23.9
1970	21.4	21.8	21.9	22.0	22.1	22.4
1971	21.8	21.9	22.0	22.2	22.3	22.4
1972	22.0	23.0	23.5	24.0	24.5	25.0
1973	20.3	21.0	21.3	21.7	22.0	22.2
1974	21.0	21.4	21.5	21.5	21.6	21.6
1975	20.9	21.0	21.2	21.3	21.8	22.0
1976	21.0	21.5	22.0	22.5	23.5	24.5
1977	21.0	20.9	21.0	21.8	22.6	22.7
1978	22.0	22.4	22.5	22.6	22.6	22.5
1979	21.3	21.0	21.2	21.4	21.7	21.9
1980	21.0	21.2	21.5	21.8	22.0	22.8
1981	21.4	21.7	22.0	22.2	22.5	22.7
1982	24.4	24.7	24.9	25.2	25.3	25.5
1983	25.3	25.4	25.8	26.2	26.3	26.4
1984	21.6	21.3	21.0	21.0	21.4	21.5
1985	20.8	20.9	21.2	21.6	21.9	22.4
1986	21.0	21.4	21.9	22.4	22.9	23.0
1987	21.5	21.4	21.9	22.3	22.6	22.7

Appendix C. FORTRAN Program Used to Average Weather Data:

Daily values of precipitation and maximum and minimum temperatures from all reporting stations within a state, are read from a data file and averaged to get one daily value for the state. They were later averaged together to obtain a yearly value.

```

program average
include 'avg.common/nolist'

fcount = 0
scount = 0          ! increment when year 1950 is found
call open_files
do while(.true.)
  call get_header
  if(year .eq. 1950) scount = scount + 1
  call get_month_data
  call process_month_data
end do
end

C -----
subroutine process_month_data
include 'avg.common/nolist'
integer count

do count = 1,days
  if( dat(count) .lt. 10000 ) then
    account(count,year-1949) =
2    account(count,year-1949) + dat(count)
    goodones(count,year-1949) = goodones(count,year-1949) + 1
  end if
end do
end

C -----
subroutine get_header
include 'avg.common/nolist'
50 read (unit=infile, err=100, end=200, fmt=1000) station, year, days
  if(year .eq. 0) then ! if TRUE probably just blank line
    read (unit=infile, err=100, end=200, fmt=1000) station, year, days
  end if
  return
100 write(*,fmt='(a27)') 'Error reading input file...'
  stop
200 call open_next_file
  goto 50
1000 format(x,t0,x1',i1,i4,t0',i1)
end

C -----
subroutine get_month_data
include 'avg.common/nolist'
mondat(1:1) = '1' ! put in the missing 1
50 read(unit=infile,
1  err=100, end=200, fmt=1000)(mondat(80*(i-1)+2:80*i-1), i=1,5)
  read(mondat,fmt=1001) (dat(i), i=1,days)
  return
100 write(*,fmt='(a27)') 'Error reading input file...'
  stop
200 call open_next_file
  goto 50
1000 format(4(x,a80/),x,a80)
1001 format(<day>(6x,i5,x))
end

```

```

C -----
  subroutine open_next_file
  include 'avg.common/nolist'
C   are we already in second file? if so.. go do averages
  if(fcount .eq. 1) then
    call do_averages
    stop
  end if
  fcount = 1
  close(infile)

  if(file2 .eq. ' ') call do_averages

  open (
  1 unit=infile, file = file2, access = 'sequential',
  1 organization = 'sequential', err = 1000, status = 'old',
  1 readonly)
  return
1000 write(*,fmt='(a22)') ' Error opening file...'
  stop
  end
C -----
  subroutine open_files
  integer stat,context
  include 'avg.common/nolist'
  call lib$set_lun (infile)
  call lib$set_lun (outfile)
  write(*,fmt='(a32)') ' Enter input name (no extention)'
  read(*,fmt='(a15)')file1

  context = 0
  file2 = file1
  file3 = file1
  call strStrim(file1,file1,1)
  file1(1+1:1-5) = '.1out'
  file2(1+1:1-5) = '.2out'
  file3(1+1:1-5) = '.avg'

  file1 = 'GPXA::DUB6:[DEMOYSE2]//file1'
  file2 = 'GPXA::DUB6:[DEMOYSE2]//file2'
  file3 = 'GPXA::DUB6:[DEMOYSE2]//file3'

  stat = lib$find_file (file1,file1,context)
  if(.not. stat) then
    write(*,fmt='(a18,a50)') ' file not found - ',file1
    stop
  end if

  stat = lib$find_file(file2,file2,context)
  if(.not. stat) then
    file2 = ' '
  end if

```

```

write(*,fmt='(a15/,2(x,a50/))') ' input file(s):',file1,file2
write(*,fmt='(a13/,x,a50/)' ) ' output file:',file3

open ( unit=infile, file = file1, access = 'sequential',
1  organization = 'sequential', status = 'old',
1  readonly, err = 1000)

open ( unit=outfile, file = file3, access = 'sequential',
1  organization = 'sequential', status = 'new',
1  err = 1000, recl = 350, carriagecontrol = 'list')
return

C  error opening some file.. give error and exit
1000 write(*,fmt='(a22)') ' Error opening file...'
      stop
      end

C -----
      subroutine do_averages
      include 'avg.common/nolist'

      integer dy,yr,montest

      real count,total(38)

      write(outfile,fmt='(a10,i3,x,a8)')
1  'processed ',scount,'stations'
      close(infile)

      do i=1,38
         montest = montest + goodones(31,i)
      end do

      if( montest .eq. 0) days = 30 ! change to 30 day month if so

      do yr = 1,38
         do dy = 1,days
            if( goodones(dy,yr) .ne. 0) then
               account(dy,yr) = account(dy,yr)/goodones(dy,yr)
            else
               account(dy,yr) = 0
            end if
            total(yr) = total(yr) + account(dy,yr)
         enddo
      enddo

      write(outfile,fmt=1002) (yr+1949,yr=1,38)
      do dy = 1,days
         write(outfile,fmt=1000) (account(dy,yr),yr=1,38)
      end do
      write(outfile,fmt=1001) (total(yr),yr=1,38)

      close(outfile)
      stop

1000 format(x,38(f7.2,x))
1001 format(//x,38(f7.2,x)///)
1002 format(x,38(i7,x))
      end

```


Appendix D. Sample of Averaged
Climatological Values.

PROCESSED 133 STATIONS
IOWA TEMPERATURE MAXIMUMS MAY

DAY	YEAR						
	1950	1951	1952	1953	1954	1955	1956
1	54.62	77.41	85.25	56.27	55.54	80.9	47.96
2	61.39	78.74	85.52	50.06	50.62	85.88	60.35
3	67.6	75.53	86.16	52.41	42.5	83.17	58.51
4	81.55	66.05	89.75	65.54	52.57	76.48	56.47
5	75	60.24	83.43	63.84	59.07	74.02	64.57
6	68.1	57.1	73.28	65.34	62.44	85.73	64.35
7	62.9	67.53	66.43	72.79	54.92	75.07	66.38
8	58.5	73.12	56.91	78.17	54.94	64.42	65.92
9	61.46	68.8	55.59	80.13	58.96	61.8	80.51
10	63.56	59.02	54.42	79.03	66.62	68.58	76.18
11	71.88	66.64	52.99	73.22	69.33	72.87	82.32
12	75.96	73.81	54.08	63.34	69.61	68	88.58
13	76.95	76.3	72.2	52.64	72.18	73.5	86.44
14	79.45	74.89	74.8	61.54	76.41	78.08	70.15
15	74.52	80.93	68.62	73.1	83.36	78.13	66.52
16	68.48	77.25	60.91	70.02	77.87	80.83	74.52
17	76.83	75.48	64.3	67.8	70.4	75.21	74.79
18	74.3	81.16	64.7	70.1	67.91	79.77	87.2
19	69.72	76.77	66.05	76.32	64.98	85.11	76.5
20	72.09	79.76	69.9	78.34	70.06	86.49	82.46
21	67.92	73.46	67.7	71.69	73.86	85.2	83.76
22	79.7	70	67.53	65.56	79.73	81.94	87.02
23	85.92	74.98	73.94	68.14	82.73	85.35	73.42
24	85.05	78.05	71.86	73.41	72.51	75.81	76.08
25	70.46	76.1	78.23	88.23	72.04	71.1	75.86
26	66.92	69.09	81.52	80.52	66.81	73.61	79.32
27	63.98	69.76	74.87	69.24	76.54	73.81	86.33
28	68.78	76.92	63.84	75.8	72.57	69.06	84.12
29	73.47	79.97	68.05	89.22	67.48	65.81	82.88
30	77.33	81.57	73.79	90.19	74.44	73.88	81.35
31	72.63	79.5	72.49	84.49	75.52	76	73.32
AVERAGE BY YEAR	71.19419	73.41709	70.61645	71.17709	67.56516	76.31	74.64967

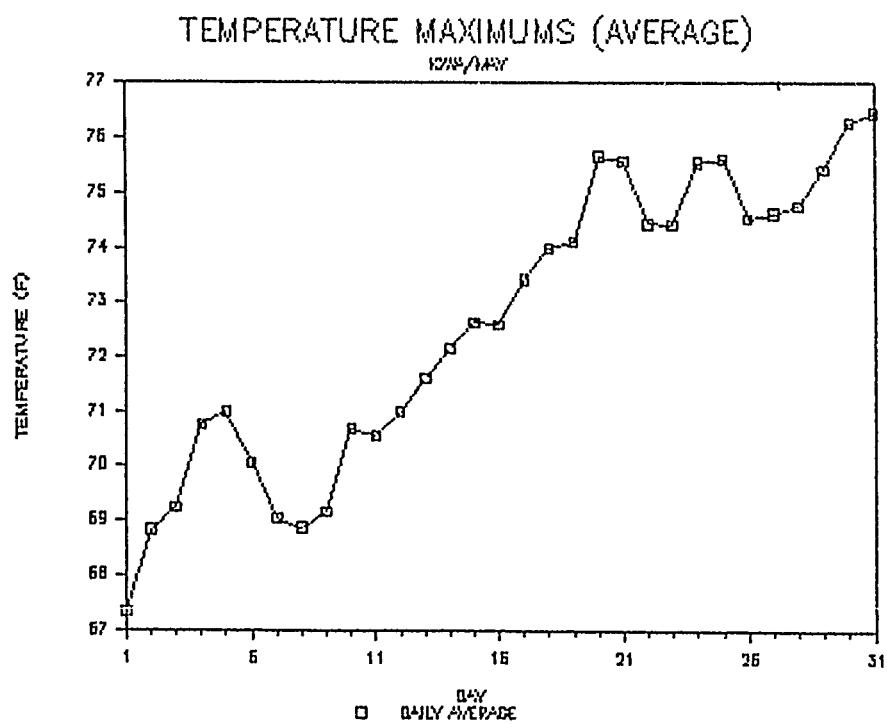
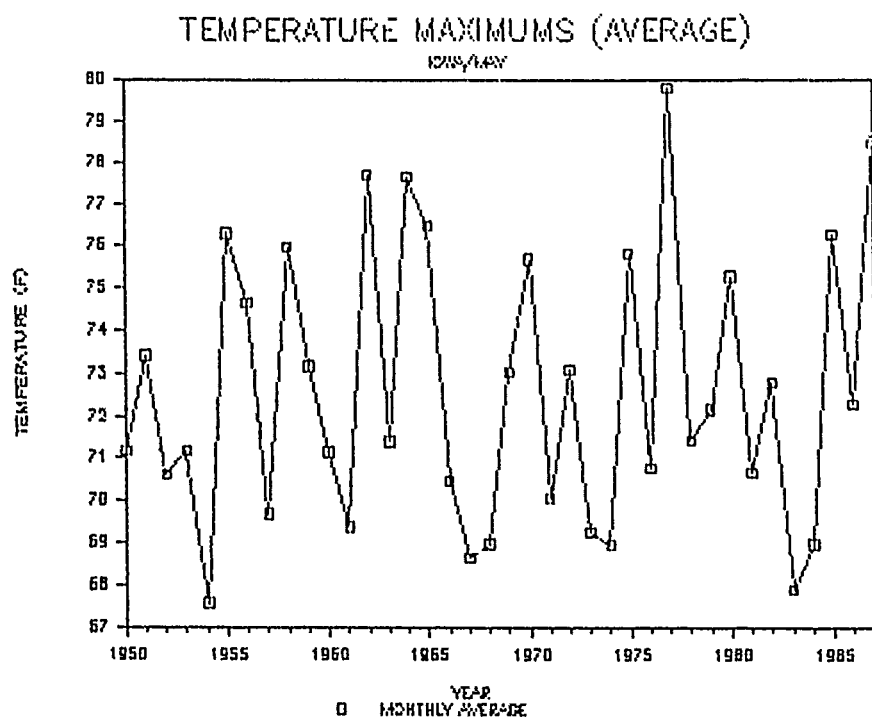
1957	1958	1959	1960	1961	1962	1963	1964
82.52	70.36	85.52	67.41	56.48	68.52	63.98	58.1
77.32	68.7	86.82	74.88	59.3	74.48	66.38	74.29
66.02	71.36	84.76	77.29	62.52	81.62	74.1	78.53
62.02	63.72	85.95	75.01	61.62	84.83	73.95	80.54
69.08	62.12	80.48	69.05	57.36	86.55	68.89	79.84
76.41	65.98	71.33	63.43	68.19	74.78	74.48	77.93
79.99	63.59	61.64	53.78	70.07	73.58	82.55	82.01
81.87	72.66	67.76	57.2	62.74	69.33	88.03	79.27
74.47	76.23	65.32	58.65	59.12	60.19	87.4	70.84
61.39	81.64	75.71	61.1	75.17	67.83	81.45	76.69
60.48	86.37	72.53	64.09	81.27	72.27	61.06	75.37
68.9	83.91	70.78	70.26	84.35	83.24	62.74	68.68
65.98	83.64	62.31	75.96	82.24	86.07	72.05	65.29
68.27	81.76	53.88	81.42	78	85.31	71.2	73.75
61.61	79.02	58.12	82.1	67.43	86.58	67.74	82.37
52.23	78.8	69.2	74.74	65.99	86.52	66.81	83.74
65.52	77.34	69.25	70.88	60.02	86.34	75.19	85.22
58.63	74.47	69.8	67.2	55.81	87.03	72.49	88.2
54.06	74.86	81.62	75.98	60.28	83.48	66.8	85.39
57.91	75.1	80.74	73.47	65.54	81.56	70.58	82.47
76.67	78.79	75.21	67.7	73.26	80.76	59.27	88.67
70.13	75.02	61.81	75.39	70.25	84.04	58.09	89.41
67.71	71.26	64.37	78.99	74.33	73.18	67.15	87.02
75.07	81.25	71.89	77.84	76.43	76.48	69.23	81.42
75.37	80.17	76.04	73.67	71.98	74.41	67.52	83.35
67.68	80.97	80.59	68.72	62.94	70.1	69.49	79.99
70.31	79.91	78.21	66.95	73.06	69.13	70.34	72.44
78.09	74.1	78.61	70.62	77.99	71.45	67.08	67.9
79.8	82.81	77.03	72.29	77.1	75.28	75.98	69.61
75.95	80.35	77.13	78.2	74.37	78.84	81.33	69.71
78.69	78.81	74.13	81.26	85.88	75.22	80.23	69.33
69.68225	75.97	73.17870	71.14612	69.39	77.70967	71.40580	77.65709

1965	1966	1967	1968	1969	1970	1971	1972
85.98	54.26	67.98	82.4	71.86	54.34	61.66	63.13
86.47	67.36	51.87	86.5	78.1	60.13	57.03	59.35
80.61	64.63	48.74	80.57	80.24	75.4	64.13	63.52
80.25	78.55	52.26	65.65	80.02	74.22	70.42	64.13
80.05	86.45	52.02	61.61	78.94	70.42	71.42	66.21
81.73	81.84	55.68	64.53	76.6	68.47	67.57	64.11
83.61	83.62	68.09	62.73	73.68	81.93	63.25	53.94
78.69	74.1	65.17	70.95	65.31	83.98	68.56	57.28
75.7	51.31	68.95	66.24	62.44	79.21	72.78	62.95
68.05	51.83	70.6	66.51	59.8	76.74	72.08	65.43
71.56	47.23	63.11	66.54	58.76	77.68	69.67	67.86
82.68	44.81	54.35	71.07	66.51	76.45	63.2	72.26
84.05	50.56	61.19	75.82	73.97	71.42	76.72	68.67
79.18	65.3	62.02	80.87	76.73	62.26	83.04	65.71
76.73	67.77	63.74	82.87	80.89	58.73	83.63	73.43
69.06	75.66	69.81	69.73	80.84	64.25	82.5	81.37
80.16	75.36	75.85	63.87	68.76	74.6	81.81	84.14
77.1	70.05	88.4	60.25	59.42	84.7	75.42	84.23
73.22	69.8	76.88	60.15	64.25	85.29	63.81	85.77
78.28	69.08	68.32	61.98	65.93	86.89	67.54	86.8
80.59	74.61	72.4	67.69	61.86	88.56	69.91	87.7
74.61	80.11	75.12	65.56	56.07	87.72	67.65	88.35
74.58	76.47	84.99	66.31	63.39	79.88	68.66	85.87
80.9	74.98	87.71	67.84	74.55	81.59	66.91	77.66
82.32	81.1	94.27	64.92	76.38	76.31	56	80.84
74.08	87.33	93.26	57.23	81.37	72.66	57.62	83.89
61.6	85.93	84.92	63.69	87.04	76.58	65.05	82.9
56.49	78.45	70.33	71.85	88.51	78.89	71.06	79.01
61.44	71.62	59.2	68.61	86.03	79.05	75.92	73.8
68.75	71.64	57.43	72.67	84.78	79.09	77.17	66.63
82.8	73.21	63.14	70.84	81.65	79.27	79.94	68.57

76.49419 70.48451 68.63870 68.96935 73.05419 75.70032 70.06870 73.08096

1973	1974	1975	1976	1977	1978	1979	1980
62.49	72.72	64.71	64.63	75.39	59.39	58.88	74.94
56.46	74.47	68.75	60.32	76.4	61.07	59.39	79.67
58.88	71.36	66.86	53.44	72.63	63.6	55.09	82.51
66.81	67.03	72.84	67.36	70.68	60.85	59.95	85.3
67.19	69.18	80.46	72.75	75.76	56.6	69.29	85.09
63.32	65.5	78.15	65.33	74.33	57.44	77.64	78.09
60.66	60.34	69.75	60.92	72.77	54.16	78.31	66.88
72.12	51.74	66.96	69.77	75.61	57.31	78.03	59.59
75.04	54.43	70.74	73.81	73.19	62.4	77.55	68.84
72.11	59.48	75.63	77.86	70.37	76.6	75.49	73.6
69.05	65.24	72.27	76.17	74.24	78.45	62.82	68.24
63.95	64.07	67.87	72.79	79.55	73.77	61.78	67.46
64.08	63.75	70.91	65.89	83.04	66.39	69.29	64.56
61.31	62.96	73.94	67.02	85.3	67.97	69.04	67.16
68.82	62.32	70.9	70.51	85.63	68.13	70.26	70.47
68.31	70.67	74.23	65.96	85.29	67.6	73.96	67.03
67.92	69.85	80.39	64.74	83.93	70.06	83.44	59.25
79	69.1	85.8	69.66	86.8	76.47	82.16	59.61
78.91	67.69	89.82	78.51	86.17	81.85	72.12	67.2
79.45	80	89.94	83.96	81.4	78.74	70.46	73.38
81.02	83.06	85.9	83.01	77.08	72.62	66.73	79.36
77.75	77.88	87.21	76.44	75.11	71.59	74.94	82.65
77.31	73.43	86.95	63.48	80	71.77	73.19	80.92
76	68.4	83.47	66.81	85.16	79.69	67.65	81.27
67.68	68.2	80.31	71.31	86.85	87.68	71.92	85.96
66.43	66.77	75.92	73.88	87.51	89	72.46	85.56
60.95	68.98	76.72	76.54	85.77	86.1	75.12	87.52
65.31	77.25	74.79	78.23	84.65	81.39	81.76	87.73
67.29	80.61	70.82	75.23	83.36	78.08	86.3	86.48
72.49	77.92	67.79	72.42	81.94	78.73	85.9	81.79
78.51	73.36	69.52	75.15	78.64	79.18	75.82	75.85
69.24580	68.94387	75.81677	70.77096	79.82419	71.44129	72.15290	75.28903

						AVERAGE	
1981	1982	1983	1984	1985	1986	1987	BY DAY
65.35	71.36	62.26	56.71	70.61	65.2	81.66	67.33552
71.63	74.95	55.17	60.76	72.12	61.39	81.6	68.83394
76.88	79.83	61.39	57.85	75.89	65.24	69.95	69.24526
70.97	83.66	63.52	57.53	78.44	77.02	65.59	70.76578
65.3	78.35	68.88	64.07	76.09	80.76	67.61	71.00105
62.78	62.07	75.54	64.76	72.61	78.85	76.18	70.05236
63.26	67.32	71.17	59.81	76.46	78.55	78.84	69.03368
62.47	73.32	59.71	54.29	80.62	80.26	80.27	68.86710
62.55	77.68	64.46	62.17	83.81	77.9	84.98	69.17368
59.04	80.92	71.46	71.28	82.39	72.59	87.53	70.67842
64.66	79.2	75.73	73.52	78.58	72.34	86	70.56868
62.93	76.18	74.61	72.96	73.72	78.23	80.22	70.99105
60.25	72.38	71	74.61	68.97	75.63	84.56	71.60421
65.68	71.63	62.89	72.72	70.24	75.54	84.53	72.15657
74.03	72.47	61.28	70.29	64.42	72.48	79.85	72.62631
74.92	76.43	66.99	73.08	60.82	67.8	84.36	72.59421
69.13	76.31	64.22	81.26	67.46	64.28	88.54	73.41842
60.24	76.82	58.43	81.75	76.68	63.86	86.75	73.98605
69.21	80.03	60.11	75.87	81.16	66.75	83.21	74.09736
75.97	78.01	65.84	77.56	77.29	68.12	84.07	75.67052
78.35	66.03	68.1	79.26	72.26	70.48	81	75.56578
77.84	57.86	70.76	75.87	74.51	71.32	65.91	74.43289
76.22	61.06	72.19	72.21	76.91	70.21	63.25	74.41421
72.16	64.63	79.27	76.77	79.61	72.1	63.61	75.55578
72.68	64.78	73.65	72.72	84.27	71.15	67.31	75.60894
75.15	67.35	70.17	64.56	87.85	67.86	76.32	74.53947
78.35	71.93	77.75	61.77	80.87	66.69	77.76	74.61605
80.52	74.14	78.81	59.88	75.12	70.66	78.59	74.74605
81.98	74.88	70.36	64.37	80.07	73.98	79.83	75.42342
79.74	75.39	62.48	70.38	84.08	79.2	81.53	76.27289
80.94	69.19	66.1	77.52	80.64	84.76	82.88	76.44684
							ERR
70.68322	72.77935	67.88064	68.97290	76.27645	72.29677	78.52548	72.59105



PROCESSED 133 STATIONS
IOWA TEMPERATURE MINIMUMS MAY

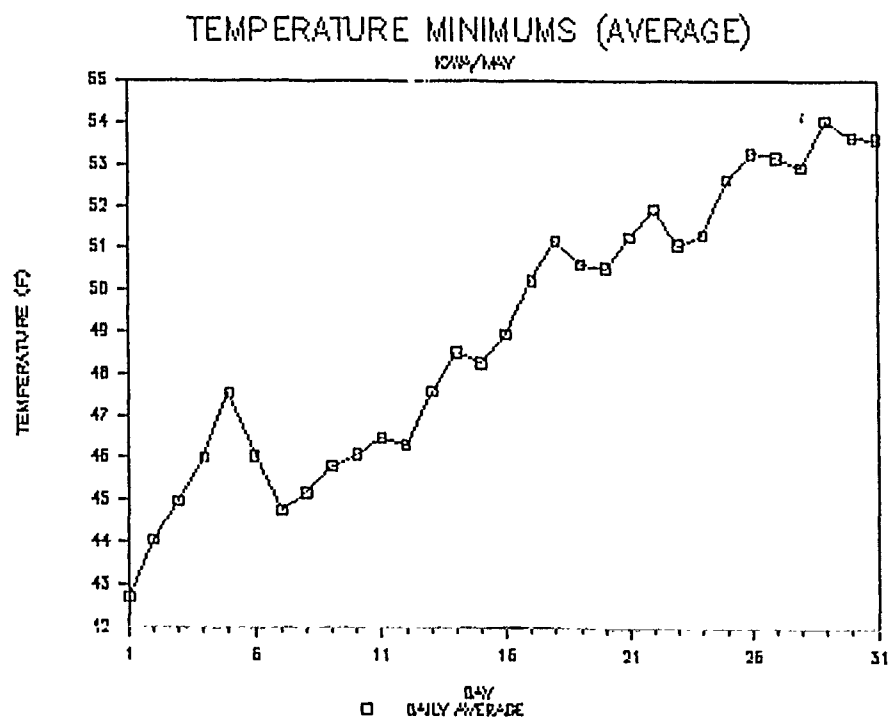
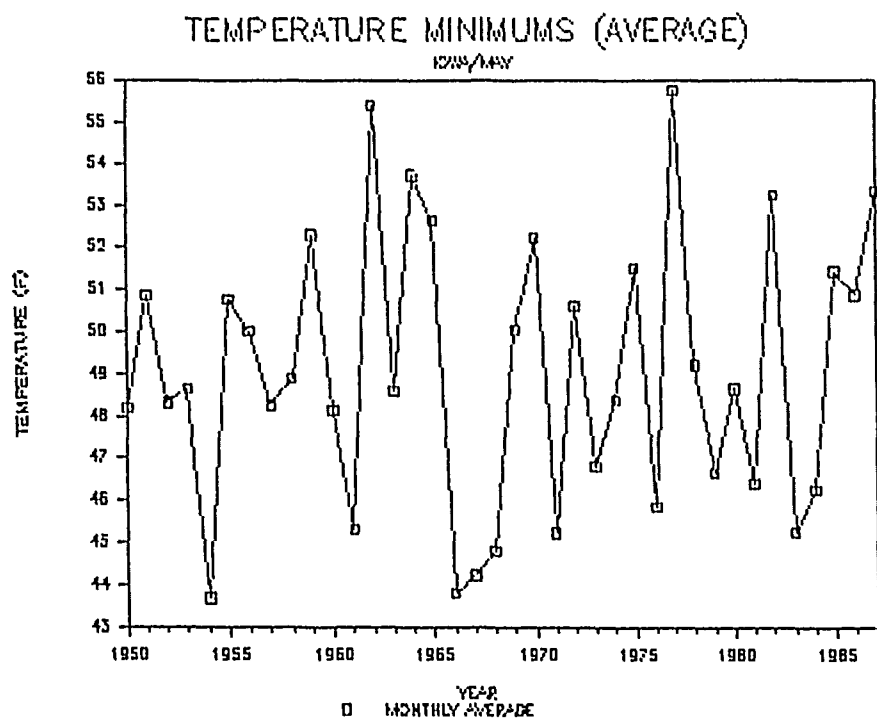
DAY	YEAR						
	1950	1951	1952	1953	1954	1955	1956
1	28.96	58.09	56.13	43.97	41.14	53.79	37.84
2	37.86	53.54	55.55	41.78	38.06	62.96	40.41
3	48.24	51.73	55.71	40.95	29.47	63.16	39.88
4	56.97	48.05	58.6	39.55	29.02	52.11	34.45
5	43.86	40.24	58.65	45.38	30.6	47.24	44.83
6	42.28	37.77	47.43	45.36	35.57	50.88	46.71
7	38.03	37.64	49.5	42.46	29.45	51.46	40.69
8	39.67	43.18	44.34	45.91	32.99	34.55	41.79
9	44.72	51.91	46.38	52.58	34.02	45.97	55.17
10	41.85	42.17	41.09	56.43	37.98	46.26	55.47
11	42.57	36.29	35.73	45.64	38.54	43.81	56.94
12	48.86	41.37	38.7	38.2	41.42	46.42	61.35
13	50.02	46.7	39.34	32.01	42.76	48.27	55.91
14	49.99	53.57	51.09	38.57	45.39	47.91	44.62
15	46.19	57.54	45.1	43.2	52.56	46.63	47.44
16	49.38	61.75	47.43	48.2	54.69	47.31	34.62
17	44.11	59.88	45.87	50.8	43.84	48.21	48.27
18	50.37	59.77	42.42	47.85	43.12	46.76	44.66
19	51.93	58.66	41.34	41.84	39.66	51.66	46.34
20	48.96	55.82	43.32	55.15	35.89	54.39	51.31
21	51.78	55.27	50.03	47.85	48.52	55.48	57.43
22	47.85	52.36	54.22	47.3	56.47	58.91	58.16
23	59.12	45.44	53.32	47.74	58.02	60.71	47.8
24	62.06	50.7	55.03	52.22	54.74	52.04	47.8
25	54.61	55.87	52.45	66.29	44.18	49.03	49.03
26	51.12	50.22	50.74	57.24	51.27	54.21	57.41
27	50.67	50.27	53.27	52.3	54.76	57.71	61.36
28	51.33	48.2	42.33	53.4	53.46	52.4	63.08
29	54.6	57.04	37.45	63.47	46.52	50.31	63.84
30	57.39	55.22	54.27	69.18	49.14	43.39	63.29
31	48.8	60.71	50.92	55.01	60.27	49.82	52.09
AVERAGE BY YEAR	48.19838	50.87	48.31451	48.63967	43.66193	50.76645	49.99967

1957	1958	1959	1960	1961	1962	1963	1964
51.53	40.88	52.68	32.62	31.34	46.15	31.7	43.91
52.45	47.17	63.06	45.02	28.74	40.7	48.08	47.5
43.49	52.73	61.53	48.93	35.8	45.95	47.7	56.89
32.39	44.13	63.85	54.2	39.06	50.25	54.32	57.64
34.49	34.33	60.96	52.46	44.41	61.55	47.98	60.34
38.57	39.75	48.47	42.32	48.61	49.6	48.83	61.11
48.4	38.48	40.04	35.76	45.12	44.07	55.84	50.85
56.29	39.7	43.53	33.47	46.48	47.41	66.04	56.48
53.22	41.4	49.87	36.71	36.78	43.92	64.26	49.38
46.28	50.14	54.47	36.28	38.56	50.17	52.34	46
43.55	53.37	43.53	36.3	52.83	50.12	44.25	53.88
50.54	54.08	50.38	34.85	53.98	58.16	46.54	48.61
54.95	52.93	44.15	42.09	60.15	66.63	51.02	44.77
54.79	57.9	37.27	48.88	58.52	64.9	47.7	43.33
46.43	56.06	35.12	53.64	47.18	65.84	49.36	53.33
40.85	56.23	39.03	55.73	38.36	66.37	49.01	58.29
45.53	58.93	45.88	48.71	48.05	65.45	53.28	58.46
45.2	52.94	54.27	51.58	45.56	64.02	49.1	63.29
44.69	44.71	56.14	57.26	46.17	61.05	47.82	61.98
44.71	40.94	62.73	55.95	49.75	55.41	38.86	51.2
52.47	44.78	57.05	50.83	45.28	58.67	38.07	56.72
48.84	56.66	50.61	50.7	44.55	61.74	30.81	64.43
44.78	40.35	47.6	53.45	39.43	55.92	32.33	66.71
45.02	49.78	45.33	58.28	44.11	51.54	41.69	57.4
58.53	47.07	58.11	56.21	52.55	54.51	46.66	50.88
51.23	55.83	63.66	54.95	35.34	53.68	52.83	60.99
44.29	54.63	54.26	52.23	39.4	54.03	57.3	51.82
48.52	40.7	59.42	51.91	50.59	58.4	53.9	48.68
56.73	48.4	57.91	56.35	50.59	59.52	48.01	46.7
58.55	59.47	60.72	49.94	48.56	57.41	52.31	48.16
59.03	61.17	59.66	54.26	58.38	54.98	58.41	45.49
48.26903	48.89161	52.29967	48.12483	45.29774	55.42322	48.59193	53.71677

1965	1966	1967	1968	1969	1970	1971	1972
54.72	29.11	38.32	48.98	49.82	37.93	36.07	49.33
57.47	33.71	28.94	51.87	55.33	29.7	34.24	42.62
57.88	35.71	28.64	51.85	55.1	41.06	31.14	41.73
56.88	38.78	32.86	41.35	54.64	45.69	42.36	42.45
58.33	57.85	38.83	32.4	54.87	47.36	47.11	41.51
61.5	49.78	33.87	43.18	59.23	39.47	47.88	48.06
62.89	49.49	35.76	49.28	51.6	49.47	45.5	42.7
59.63	43.13	43.89	43.99	47.29	57.29	40.81	41.33
56.86	29.58	35.59	41.8	40.16	55.85	40.78	39.49
43.36	29.61	49.82	36.25	37.1	47.09	50.3	40.64
41.94	34.25	42.32	42.13	36.85	55.08	50.44	47.03
46.22	36.83	38.83	38.06	33.33	59.64	34.45	50.1
51.47	37.99	38.58	49.93	46.84	55.1	38.83	51.39
57.22	35.76	44.53	55.42	50.27	49.95	46.35	49.93
59.25	50.3	38.39	53.87	54.09	45.24	53.22	46.05
53.05	41.71	39.8	43.74	57.69	41.15	49.3	51.7
47.83	52.83	43.71	38.07	47.17	43.2	58.3	55.94
54.97	46.6	54.71	39.45	45.24	55.43	55.91	56.27
42.52	44.49	47.85	39.06	45.54	59.43	45.1	56.48
52.25	44.34	38.95	39.65	44.58	60.18	41.71	56.67
60.78	46.58	42.88	39.62	43.3	66.23	47.69	58.19
54.83	52.23	40.02	43.96	41.15	63.46	50.83	60.76
53.14	54.16	54.94	46.07	42.54	60.6	53.65	59.34
59.31	44.26	53.5	42.72	45.38	60.03	51.39	58.12
61.94	47.22	61.39	48.65	50.55	54.42	44.75	55.66
55.48	54.29	65.25	48.81	54	44.28	38.87	59.73
41.02	59.8	59.84	45.1	62.9	50.93	36.79	59.35
37.12	48.53	51.38	45.1	64.79	56.79	39.64	61.6
37.83	43.89	49.45	48.59	64.28	61.95	44.63	57.88
42.47	42.9	49.13	45.98	56.08	61.95	49.1	47.9
51.42	42.2	49.22	53.64	59.93	63.32	55.14	39.3
52.63161	43.80354	44.23032	44.79258	50.05290	52.23451	45.23483	50.62096

1973	1974	1975	1976	1977	1978	1979	1980
49.31	40.96	35.66	38.15	52.82	33.21	33.56	43.41
38.61	48.85	45.28	35.7	50.98	30.57	45.56	45.65
34.42	38.83	47.76	29.87	53.53	34.41	37.08	47.75
35.74	41.17	43.13	34.73	56.74	42.87	35.19	47.58
48.07	45.09	50.61	52.56	52.54	38.94	41.85	52.63
52.04	34.16	51.76	37.95	53.62	35.2	48.96	42.98
52.75	40.01	50.91	32.38	48.91	43.4	55.58	35.14
50.01	41.16	49.36	33.94	50.23	45.06	56.98	32.88
53.38	41.02	47.87	44.5	41.47	43.6	53.07	32.21
49.18	41.98	47	47.44	40.19	40.22	50.9	48.55
45.76	48.39	51.82	43.27	45.24	56.59	38.88	40.36
41.87	44.25	45.78	47.41	48.14	51.11	34.5	41.77
38.02	41.79	43.32	47.36	51.63	45.11	41.55	44.48
36.36	46.74	51.02	45.88	56.59	43.21	46.12	37.46
33.9	40.49	42.34	49.29	61.96	44.32	40.38	44.11
44.86	50.39	41.95	51.67	61.74	47.57	46.55	47.85
35.42	53.63	48.07	43.06	61.69	49.79	58.52	49.05
47.61	54.56	55.62	39.17	62.8	49.18	58.41	50.66
51.32	53.96	63.94	47.38	62.4	56.31	48.36	49.19
47.65	59.53	67.92	57.35	60.07	53.62	49.95	47.69
58.38	64.47	62.23	58.75	58.07	45.91	38.98	48.39
58.16	56.08	62.39	54.04	58.19	49.74	46.66	50.85
47.65	48.57	64.81	49.44	55.67	55.95	47.54	53.64
53.09	44.66	57.46	43.98	59.42	57.78	39.6	56.95
48.86	45.78	59.66	43.12	61.77	64	40.17	57.77
48.25	51.16	55.28	46.29	63.11	66.18	48.58	61.34
52.65	51.49	46.08	51.08	61.69	4.75	46.11	60.39
51.23	59.2	54.12	52.19	59.93	1.55	48.27	61.13
49.06	61.67	57.87	54.84	60.39	60.07	57.6	64.2
46.48	58.16	51.9	55.17	59.33	56.27	58.4	59.11
51.39	51.48	43.96	54.13	58.12	58.17	52.64	53.84
46.82193	48.37677	51.51225	45.87387	55.77354	49.21483	46.66129	48.67774

							AVERAGE
1981	1982	1983	1984	1985	1986	1987	BY DAY
41.32	40.88	44.59	33.79	51.16	43.49	45.22	42.69842
39.55	42.71	42.32	40.95	41.92	35.46	53.68	44.06710
51.87	49.45	41.39	41.73	43.65	41.52	50.77	44.98157
55.51	58	41.65	38.22	51.98	51.61	45.07	46.02078
47.8	54.22	41.13	39.14	56.04	58.67	41.99	47.54894
40.44	44.94	51.99	45.91	48.81	52.22	42.97	46.05605
35.13	40.08	46.26	43.21	48.74	49.06	44.96	44.76315
44.65	46.21	34.17	34.53	47.26	56.87	44.82	45.19263
44.85	53.19	37.57	37.21	54.59	56.41	53.46	45.81052
32.83	58.55	43.86	43.97	59.09	57.48	60.72	46.09526
32.3	58.6	49.06	50.09	59.7	56.61	61.96	46.47421
38.7	58.69	54.09	44.76	54.32	56.02	47.75	46.31789
44.3	59.74	48.9	52.1	46.53	53.63	48.66	47.60394
42.96	58.64	41.89	43.7	51.5	48.31	59.77	48.52657
40.95	54.62	35.18	47.29	49.46	55.16	48.84	48.27157
47.22	55.25	40.27	48.13	49.66	50.69	51.15	48.95631
50.5	58.17	44.01	52.87	46.63	49.23	56.46	50.24789
44.78	55.05	47.84	59.02	46.05	44.41	60.63	51.19157
39.51	56.54	49.81	59.11	51.62	43.98	58.24	50.61552
39.2	57.44	45.86	53.97	51.9	43.46	62.25	50.54157
44.75	45.87	47.49	55.31	43.91	42.41	58.49	51.28710
55.23	48.67	51.87	56.27	46.35	44.58	44.18	51.95026
58.28	50.32	42.6	46.63	50.61	48.54	44.43	51.10105
49.63	51.61	49.29	53.47	51.83	50.28	48.58	51.31789
49.14	55.05	47.33	49.85	53.7	51.7	51.69	52.63552
52.2	56.31	41.17	42.51	61	51.76	57.98	53.27763
53.98	56.01	51.21	47.2	55.44	56.13	62.59	53.17973
58.08	55.72	54.24	44	51.38	56.56	62.52	52.95763
59.11	60.31	47.43	39.12	54.08	58.31	63.71	54.045
54.11	56.55	42.98	42.14	59.69	54.63	60.98	53.64236
49.79	53.44	45.19	48.48	56.23	58.46	59.24	53.62447
							ERR
46.40870	53.25258	45.24645	46.28	51.44612	50.89193	53.34709	49.06452



PROCESSED 212 STATIONS
IOWA PRECIPITATION MAY

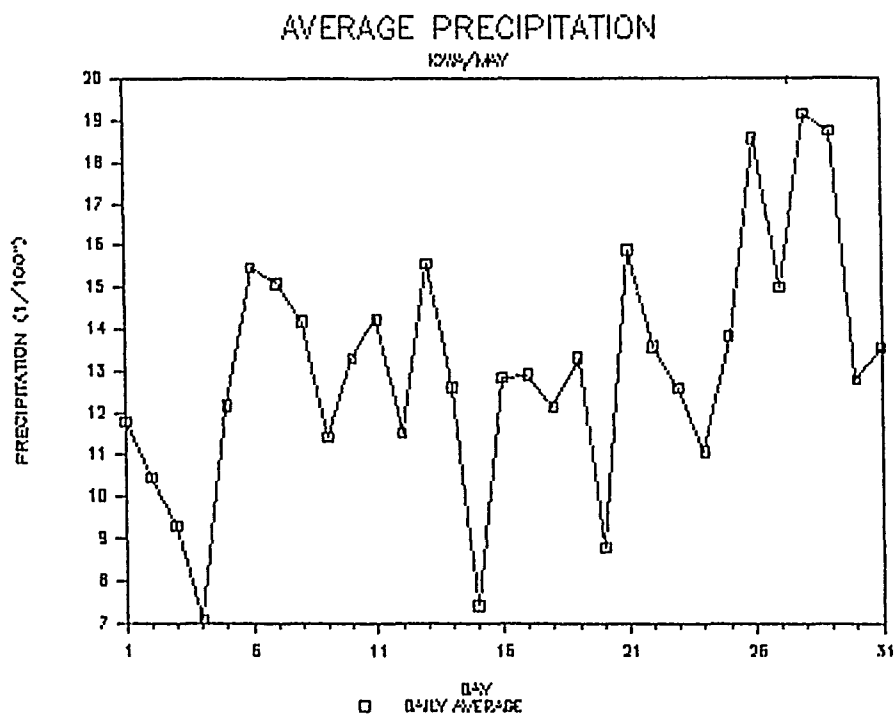
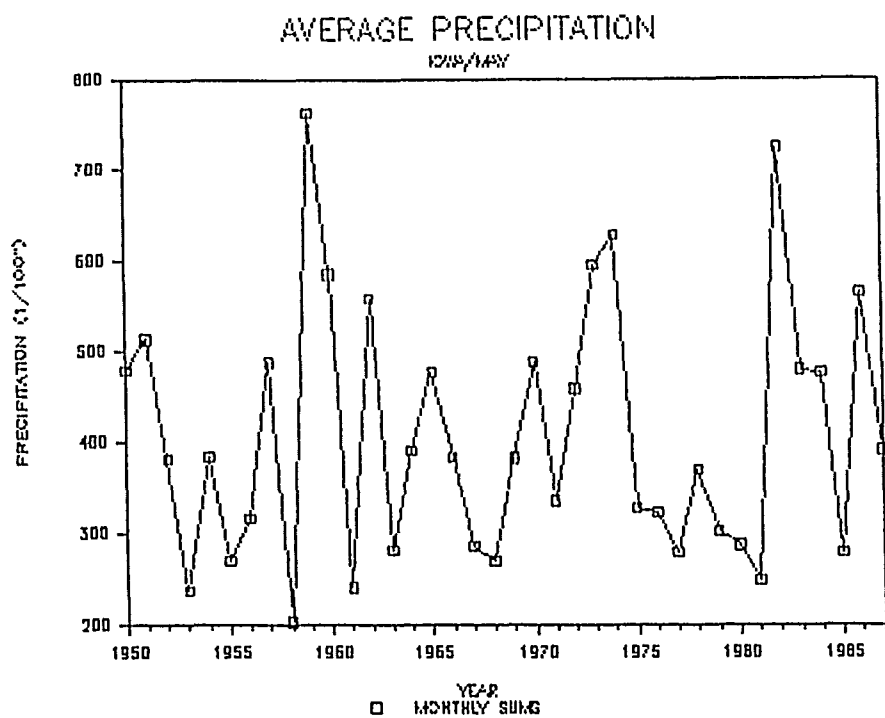
DAY	YEAR						
	1950	1951	1952	1953	1954	1955	1956
1	0.16	70.92	1.52	20.35	41.46	1.95	16.84
2	0.74	8.98	3.98	9.7	69.15	1.82	25.28
3	1.56	1.83	8.23	7.2	16.69	4.85	18.54
4	24.88	2.3	0.1	1.62	0.24	13.69	7.68
5	48.4	3.98	0.46	5.21	0.02	0	17.45
6	1.23	9.78	0.69	7.2	0.08	2.35	7.82
7	0.08	0.15	51.21	0.22	0.07	9.67	0.19
8	65.11	0.14	18.32	0	0.69	0.06	0.02
9	125.01	48.72	38.31	0	0.62	47.41	5.59
10	0.32	73.47	7.74	15.89	0.01	33.69	21.06
11	0.1	9.51	1.92	7.16	0.17	0	30.44
12	3.23	0	0.98	0.28	0	5.9	0.6
13	3.6	0	0.01	0.03	0	14.32	26.11
14	0.13	11.87	4.3	0.13	0	0.1	1.62
15	0.81	6.11	2.91	0.05	1.32	0	0.03
16	18.41	12.44	43.24	4.73	1.86	0	0.83
17	4.31	17.04	14.18	13.02	0.43	0	1.88
18	6.48	8.05	0.1	5.55	3.78	0	1.13
19	16.72	21.05	0	0.72	2.18	0	2.21
20	16.12	7.91	1.61	7.39	0.24	0.06	0.78
21	43.9	12.3	16.79	37.63	0	0.09	1.38
22	4.38	18.36	68.22	42.51	1.69	3.66	2.99
23	2.32	1.65	48.63	0.88	21.4	13.62	4.51
24	16.63	1.58	3.54	32.2	11.17	17.92	0
25	37.35	41.2	1.87	8.8	0.11	2.27	0.55
26	4.27	46.75	0.17	1.58	14.58	27.44	0.82
27	6.71	1.95	24.55	2.79	46.06	31.47	7.63
28	4.16	0.12	6.1	2.35	81.35	26.57	29.4
29	14.91	2.61	0.79	0.12	4.18	9.38	46.27
30	5.42	1.59	3.36	0.58	2.55	0.55	36.08
31	1.5	70.89	7.89	0	61.9	0.46	0.45
MONTHLY SUM BY YEAR	478.95	513.25	381.72	235.89	384	269.3	316.18

1957	1958	1959	1960	1961	1962	1963	1964
0.01	0.03	0.02	2.49	0	3.98	0.36	13.49
0.01	5.94	5.06	3.46	0	0.16	5.7	10.38
0.04	13.8	38.47	3.76	0	0	10.67	4.92
0	19.96	8.68	7.24	8.75	0.04	34.25	13.28
0	4.11	65.98	32.28	32.55	10.24	0.56	6.45
0	0.1	46.3	112.21	13.35	31.42	0.27	33.71
0.01	6.57	2.57	45.76	6.35	14.96	0.2	13.15
1.06	8.55	0.53	3.79	11.06	48.24	0	49.87
17.72	0	26.55	0.04	0.12	2.2	4.3	4.19
74.17	0	50	2.16	0	4.6	29.36	0.32
12.99	0.05	27.58	3.02	0	20.08	16.17	4.11
27.13	0.24	4.45	0	0	26.03	54.26	43.91
43.36	0.17	4.27	0	0.44	0.69	29.4	28.01
62.79	9.37	0.18	0	11.84	1.39	3.21	0.49
7.79	3.75	0.74	1.21	20.2	0.1	26.29	3.99
8.68	5.48	0.03	86.04	5.97	1.12	3.75	11.9
21.79	28.87	0.19	15.16	46.42	3.38	10.01	1.91
2.28	14.41	19.03	18.58	18.51	12.75	0.65	1.57
2.16	0.03	40.68	31.67	0.12	22.83	0.49	1.81
9.88	0.39	48.32	44.31	1.57	1.05	1.11	0.81
50.57	0.72	75.72	55.63	0.38	35.53	3.46	0.01
5.8	5.23	9.39	5.58	0.02	23.08	0	0.54
3.91	0.81	10.46	0.72	0	20.57	0	15.37
0.46	1.19	0.08	18.29	0.17	0.72	0.46	69.73
26.84	2.12	0.53	66.29	22.76	3.46	1.44	3.88
15.46	2.07	8.77	17.42	3.56	62.56	1.91	51.14
0.05	7.67	9.51	3.76	0	15.94	22.33	1.67
1.01	0	47.12	0.81	1.07	62.15	17.87	0.07
29.08	0.08	87.53	1.12	0.35	121.15	1.54	0
46.96	12.76	53.51	0.86	13.16	7.62	0.14	0.08
15.36	48.18	72.15	1.74	21.4	1.1	1	0.48
487.37	202.65	764.4	585.4	240.12	559.14	281.16	391.24

1965	1966	1967	1968	1969	1970	1971	1972
0.2	0.02	9.33	0.01	4.38	27.73	6.51	69.96
0.19	0	1.22	0.14	9.95	0.17	3.01	21.25
0.22	0.86	2.62	3.04	12.23	0.14	0.16	3.63
3.93	0.02	3.43	0.25	2.29	0.95	4.59	3.23
24.6	0.07	6.88	0.58	6.39	1.25	7.82	13.34
7.54	0	5.21	6.32	46.33	0.44	17.64	61.04
4.71	3.99	2.95	25.6	27.23	0	25.74	45.38
44.37	9.15	3.8	16.9	40.64	0.04	12.23	24.2
16.91	3.55	0.13	0.32	2.36	12.34	0.23	1.3
0.21	1.94	30.81	0	19.63	17.68	7.79	0.82
0.01	79.71	59.94	0.09	3.01	25.77	12.55	4.58
0.01	53.99	0.18	0	1.34	36.79	1.18	12.5
1.61	8.59	0.08	8.27	7.19	101.79	0	35.08
5.01	2.91	0.24	35.31	1.7	81.7	0	14
31.69	32.53	0.32	9.65	0.07	10.14	0.1	4.89
24.36	9.29	1.15	23.57	21.52	1.58	0.31	0.83
0.7	40.36	0.56	0.17	40.34	0	5.7	0.88
11.57	1.41	1.43	8.13	7.65	0	63.89	0.99
0.07	1.47	5.02	6.66	7.59	0	61.66	0
0.12	10.71	0	0.89	12.1	0	1.72	0
22.5	10.61	0.01	0.27	54.11	0.11	0.77	0
52.99	1.11	0.04	4.26	35.88	4.1	0.89	0.27
34.4	75.05	1.42	9.57	0.05	30.45	22.33	22.69
16.44	35.34	0	1.07	1.53	27	44.94	27.42
39.83	0	0.02	16.44	4.97	23.57	7.84	5.77
93.85	0	0.01	49.86	3.94	0.03	0.08	10.68
11.01	0.05	7.05	7	0.16	8.24	0	16.78
0.55	0.01	49.48	7.63	0.1	22.45	0	17.91
14.86	0.08	13.65	11.99	1.23	20.6	0	28.01
8.46	0.57	49.29	0.84	0	17.23	1.59	11.32
3.15	0	28.78	14.74	6.34	16.22	24.42	0.27
476.07	383.39	35.05	269.57	382.25	488.51	335.69	459.02

1973	1974	1975	1976	1977	1978	1979	1980
84.35	0	0.33	1.6	0.75	0.16	4.05	0.07
61.1	0.7	3.75	8.93	2.99	0	40.6	0.03
0.79	7.99	12.18	0.61	12.99	0	50.76	0.16
0	0.01	0.73	0	30.91	1.33	0	0.04
2.02	0.01	2.01	2.64	48.39	10.34	0	0.24
23.29	0.01	6.25	19.89	13.31	9.25	0	0.04
67.98	25.49	23.23	1.73	9.19	64.96	0	0
48.8	38.4	23.21	0	3.49	32.16	12.71	0
5.51	1.45	0.24	0	1.88	2.47	14.11	0.08
11.9	10.42	0.27	0.11	0	0.32	16.25	7.64
0.26	66.86	33.28	0.07	0	4.08	29.5	10.5
1.21	4.72	14.92	7.09	0.09	28.08	0.78	1.86
0.25	30.74	0.2	28.1	0	87.26	5.28	19.13
1.17	56.19	1.46	7.97	0.14	4.66	6.81	2.82
0.03	1.07	2.56	11.93	5.79	0.96	4.09	4.25
0	41.72	0	54.93	9.36	0.02	0.02	8.84
0	50.68	0	16.05	5.53	0	0.57	38.34
0.14	73.44	0.48	0	3.2	0.03	22.9	18.59
0.23	32.7	0.25	0	7.6	2.43	48.98	6.44
0.48	9.77	0.46	0.42	23.87	16.09	0.32	0.05
6.82	14.7	18.28	3.1	26.05	0.01	0.08	0.07
16.34	18.75	8.94	47.3	21.55	2.17	0.86	0
0.74	0.66	11.59	48.65	2.23	11.12	1.62	0.33
6.28	1.35	5.53	6.85	0.2	0.52	0.01	0.53
14.41	2.38	11.05	0.06	1.39	0.62	0.17	0.09
26.74	30.09	20.71	0	4.51	3.08	8.23	3.32
130.76	11.64	0.53	0.79	16.2	11.12	10.49	8.63
78.14	29.93	38.48	5.75	12.57	29.89	0.25	9.62
5.96	37.64	44.73	35.59	5.61	26.51	3.84	46.64
0.69	13.01	35.86	11.49	5.83	9.41	5.25	84.16
0	15.66	6.2	0.81	2.17	10.44	13.92	14.29
596.39	628.18	327.71	322.46	277.79	369.49	302.45	286.8

						AVERAGE BY DAY	
1981	1982	1983	1984	1985	1986	1987	
0.87	0.04	30.23	1.37	16.87	15.48	0.22	11.79236
0.2	0	68.88	11.79	2.44	0.36	9.68	10.46684
8.26	0	31.89	34.91	0	3.59	35.63	9.295263
41.07	9.44	0.92	13.42	0	0.01	10.28	7.093684
12.17	75.69	1.56	6.85	7.84	2.33	1.49	12.16315
0	61.91	9.69	9.57	20.36	2.79	0.85	15.48
0	23.51	41.44	17.96	0.68	10.73	0	15.09631
1.32	4.55	3.71	0.14	0.19	11.27	0	14.17684
3.89	2.09	0.28	0.02	0.06	43.91	0.48	11.43131
4.49	3.87	0.06	2.47	0.71	53.65	1.51	13.29842
1.47	18.17	1.44	6.61	16.66	30.2	2.88	14.23526
6.67	38.68	18.88	2	31.89	6.94	0.85	11.51736
16.44	24.28	23.87	11.87	7.7	22.12	1.78	15.58
21.51	30.39	12.01	0.11	55.09	24.53	6.23	12.61526
3.44	29.79	6.6	0.33	20.57	25.43	0.19	7.413684
0.13	18.44	0.16	1.51	5.34	60.49	0	12.84342
9	25.72	6.72	1.17	1.34	68.29	0.17	12.91789
23.38	22.7	38.19	17.81	0.03	21.38	10.69	12.12894
4.1	16.45	77.69	54.39	3.17	0.01	26.4	13.31526
0	23.25	2.33	21.23	28.05	0	41	8.800263
0.06	61.06	12.34	1.81	0.93	0	36.1	15.89210
6.54	36.83	23.76	40.22	0.04	0.11	1.57	13.57815
38.08	2.96	1.85	10.58	5.05	1.41	0.35	12.57973
26.81	18.21	3.45	5.57	8.99	4.75	4.88	11.10026
0.01	17.84	11.77	95.68	0.01	24.26	27.8	13.82763
0.4	61.32	0.96	3.91	0.68	52.99	72.35	18.58526
1.2	24.18	10.6	18.86	10.49	36.77	45.54	15.00473
6.87	10.34	19.1	77.32	2.12	18.66	11.26	19.17315
9.99	30.39	11.73	6.6	4.63	16.16	14.84	18.74710
0.22	16.84	3.34	0	11.8	6.13	7.64	12.79447
0	15.9	4.59	0	10.27	0	18.74	13.53710
							ERR
248.59	724.84	480.04	476.08	79	564.75	391.4	406.4813



Appendix E. Sample Printout from CERES-Maize

Welcome to the C E R E S M A I Z E Model Version 2.10.
Version 2.10 incorporates new menu structure, supports
multi-year and multi-treatment simulation, and also
provides output support for IBSNAT graphics and DSSAT.

Please press "Enter" to continue

LIST OF EXPERIMENTS TO BE SIMULATED		INST. ID	SITE ID	EXPT. NO	YEAR
1)	N X VAR WAPIO, IBSNAT EXP.1983-4	IB	WA	01	1983
2)	N X IRRIGATION, GAINESVILLE	UF	GA	01	1982
3)	N X IRRIG., S.C. (CERES MAIZE BK)	FL	SC	01	1981
4)	MULTI-YEAR TEST, SITIUNG	IS	SI	01	1980

1) <=== CURRENT EXPERIMENT SELECTION.
<--- NEW SELECTION?

3
2J

TRT NO.	N X IRRIG., S.C. (CERES MAIZE BK)	INST. ID	SITE ID	EXPT. NO	YEAR
1)	Plo 3382 200 kg N/ha IRR	FL	SC	01	1981
2)	Plo 3382 200 kg N/ha NO IRR	FL	SC	01	1981
3)	Run all treatments without keyboard inputs				

1) <=== CURRENT TREATMENT SELECTION.
<--- NEW SELECTION?

2
2J

RUN-TIME OPTIONS?

- 0) RUN SIMULATION
- 1) SELECT SIMULATION OUTPUT FREQUENCY
- 2) MODIFY SELECTED MODEL VARIABLES INTERACTIVELY.

<=== CHOICE? [DEFAULT = 0]

2
2J

MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

VARIABLES TO BE MODIFIED

1. Planting Date, Simulation Date and Seeding Depth
2. Plant Population
3. Nitrogen Non-Limiting
4. Irrigation Inputs and Water Balance Switch
5. Fertilizer Inputs
6. Select New Variety
7. Soil Profile Inputs (Water Balance, Root Preference, DMOD)
8. Select Weather Data
9. Initial Soil Fertility and Water, and Crop Residue Parameters
10. Display Echo
11. End of Changes
12. Abandon all Changes and Return to Experiment Menu

ENTER NUMBER OF MODIFICATION : 1

Do you want to

1. Change Planting Date ?
2. Change Simulation Date ?
3. Change Seeding Depth (cm) ?
4. Return to main menu ?

Enter number of choice : 1

Existing Planting Date is 97 .

Input New Planting Date : 135

Do you want to

1. Change Planting Date ?
2. Change Simulation Date ?
3. Change Seeding Depth (cm) ?
4. Return to main menu ?

Enter number of choice : 2

Input New Date to Begin Simulation : 135

- Do you want to
1. Change Planting Date ?
 2. Change Simulation Date ?
 3. Change Seeding Depth (cm) ?
 4. Return to main menu ?

Enter number of choice : 4

MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

VARIABLES TO BE MODIFIED

1. Planting Date; Simulation Date and Seeding Depth
2. Plant Population
3. Nitrogen Non-Limiting
4. Irrigation Inputs and Water Balance Switch
5. Fertilizer Inputs
6. Select New Variety
7. Soil Profile Inputs (Water Balance, Root Preference, DMOD)
8. Select Weather Data
9. Initial Soil Fertility and Water,
and Crop Residue Parameters
10. Display Echo
11. End of Changes
12. Abandon all Changes and Return to Experiment Menu

ENTER NUMBER OF MODIFICATION : 6

===== VARIETIES IN THE DATA BASE =====

The current variety is 12 .

NO.	VARIETY NAME	P1	P2	P5	G2	G3
---	-----	---	---	---	---	---
1	CORN251	110.00	.3000	685.00	825.40	6.600
2	CP170	120.00	.0000	685.00	825.40	10.000
3	LG11	125.00	.0000	685.00	825.40	10.000
4	F7 X F2	125.00	.0000	685.00	825.40	10.000
5	PI0 3995	130.00	.3000	685.00	825.40	8.600
6	INRA	135.00	.0000	685.00	825.40	10.000
7	ED0	135.00	.3000	685.00	825.40	10.400
8	A654 X F2	125.00	.0000	685.00	825.40	10.000
9	DEKALB XL71	140.00	.3000	685.00	825.40	10.500
10	F478 X W705A	140.00	.0000	685.00	825.40	10.000
11	DEKALBXL45	150.00	.4000	685.00	825.40	10.150
12	PI0 3382	160.00	.7000	890.00	750.00	8.500
13	B59*0H43	162.00	.8000	685.00	784.00	6.900
14	F16 X F19	165.00	.0000	685.00	825.40	10.000

PRESS <Enter> TO CONTINUE LISTING.

NO.	VARIETY NAME	P1	P2	P5	G2	G3
43	P10 511A	220.00	.3000	685.00	645.00	10.500
44	W69A X F546	240.00	.3000	685.00	825.40	10.000
45	A632 X VA26	240.00	.3000	685.00	825.40	10.000
46	W64A X W117	245.00	.0000	685.00	825.40	8.000
47	P10 3147	255.00	.7600	685.00	834.00	10.000
48	WF9*E37	260.00	.8000	710.00	825.40	6.500
49	NEB 611	260.00	.3000	720.00	825.00	9.000
50	PV62S	260.00	.5000	750.00	600.00	8.500
51	PV76S	260.00	.5000	750.00	600.00	8.500
52	P10 3183	260.00	.5000	750.00	600.00	8.500
53	CEEDA-2S	260.00	.5000	669.00	780.00	7.100
54	B14*OH43	265.00	.8000	665.00	780.00	6.900
55	MCCURDY 6714	265.00	.3000	825.00	825.40	9.200
56	FM 6	276.00	.5200	867.00	616.00	10.700

PRESS <Enter> TO CONTINUE LISTING.

NO.	VARIETY NAME	P1	P2	P5	G2	G3
57	TCCORON-3	276.00	.5200	867.00	600.00	8.120
58	NC-59	280.00	.3000	750.00	825.00	10.000
59	H6	310.00	.3000	685.00	825.40	10.000
60	H610(UH)	300.00	.5200	920.00	580.00	6.400
61	FE 6	300.00	.5200	990.00	400.00	7.000
62	B56*C-121A	318.00	.5000	700.00	805.00	6.400
63	P10 X 304C	320.00	.5200	940.00	625.00	6.000
64	H.OBREGON	360.00	.8000	625.00	825.40	10.150
65	SUWAN-1	380.00	.6000	780.00	750.00	7.000

The current variety is 12 .

Do you want to

1. Select a new variety ?
2. Create a new variety ?
3. Modify current genetic coefficients ?
4. View the varieties again ?
5. Return to the main menu ?

Enter number of choice : 1

New Variety : 2

NO.	VARIETY NAME	P1	P2	P5	G2	G3
43	P10 S11A	220.00	.3000	685.00	645.00	10.500
44	W69A X F546	240.00	.3000	685.00	825.40	10.000
45	A632 X VA26	240.00	.3000	685.00	825.40	10.000
46	W64A X W117	245.00	.0000	685.00	825.40	8.000
47	P10 3147	255.00	.7600	685.00	834.00	10.000
48	WF9*B37	260.00	.8000	710.00	825.40	6.500
49	NEB 611	260.00	.3000	720.00	825.00	9.000
50	PV62S	260.00	.5000	750.00	600.00	8.500
51	PV76S	260.00	.5000	750.00	600.00	8.500
52	P10 3163	260.00	.5000	750.00	600.00	8.500
53	CEEDA-2S	260.00	.5000	669.00	780.00	7.100
54	B14*OH43	265.00	.8000	665.00	780.00	6.900
55	MCCURDY 6714	265.00	.3000	825.00	825.40	9.200
56	FM 6	276.00	.5200	867.00	616.00	10.700

PRESS <Enter> TO CONTINUE LISTING.

NO.	VARIETY NAME	P1	P2	P5	G2	G3
57	TUCORON-3	276.00	.5200	867.00	600.00	8.120
58	NC-59	280.00	.3000	750.00	825.00	10.000
59	H6	310.00	.3000	685.00	825.40	10.000
60	H6-10(UH)	300.00	.5200	920.00	580.00	6.400
61	FE 6	300.00	.5200	990.00	400.00	7.000
62	B56*C121A	318.00	.5000	700.00	605.00	6.400
63	P10 X 304C	320.00	.5200	940.00	625.00	6.000
64	H.OBREGON	360.00	.8000	625.00	825.40	10.150
65	SUWAN-1	380.00	.6000	780.00	750.00	7.000

The current variety is 12 .

Do you want to

1. Select a new variety ?
2. Create a new variety ?
3. Modify current genetic coefficients ?
4. View the varieties again ?
5. Return to the main menu ?

Enter number of choice : 1

New Variety : 2

SOILS IN THE DATA BASE.		
REF	TAXONOMY NAME	LOCATION
1)	DEEP SILTY CLAY	
2)	MEDIUM SILTY CLAY	
3)	SHALLOW SILTY CLAY	
4)	DEEP SILT LOAM	
5)	MEDIUM SILT LOAM	
6)	SHALLOW SILT LOAM	
7)	DEEP SANDY LOAM	
8)	MEDIUM SANDY LOAM	
9)	SHALLOW SANDY LOAM	
10)	DEEP SAND	
11)	MEDIUM SAND	
12)	SHALLOW SAND	
13)	Waipio (Clayey, kaolinitic, isohyperth, Tropeptic Eutruston)	Waipio, HI
14)	Millhopper Fine Sand (Loamy, silic, hyperth Arenic Paleudult)	Gainesville
15)	Millhopper Fine Sand (Loamy, silic, hyperth Gross. Paleudults)	Gainesville
16)	Lake Fine Sand (Hyperthermic, coated Typic Quartzipsamments)	Gainesville
17)	Orangeburg Sandy Loam (F-loamy, silic, thermic Typ Paleudults)	Quincy, FL
18)	Haynie (Coarse-silty, mixed, calcareous, mesic Typ Udifluvent)	Manhattan, KS
19)	Wood Mountain Loam (Orthic Brown Chernozem)	Swift, CAN
20)	Rothamsted	Rothamsted
21)	Tel Hadya (Palexerollic Chromoxerert; high AWC)	Aleppo, SYR
22)	Tel Hadya (Palexerollic Chromoxerert; low AWC)	Aleppo, SYR
23)	Norfolk Loamy Sand	Florence, SC
24)	Norfolk Sandy Loam (F-loamy, silic, thermic Typ Paleudults)	Marianna, FL
25)	Norfolk Sandy Clay Loam (F-1, silic, therm. Typ. Paleudults)	Raleigh, NC
26)	Ma Silt Loam	Castana, IO
27)	Sitting (no subsoil acidity, Ultisol)	Sumatra, IND
28)	Subsoil acidity, Ultisol)	Sumatra, IND
29)	Patancheru (Alfisol Udic Rhodustalf)	Hyderabad, IN

The current soil is number 23 .

Do you want to

1. Select a new soil ?
2. Modify or view parameters of current soil ?
3. View the soils again ?
4. Return to the main menu ?

Enter number of choice : 1

Input new soil selection : 5

WEATHER DATA SETS AVAILABLE	DATES AVAILABLE		INST ID	WEATHER STATION ID
	FROM	UNTIL		
1) 1983 WAIPIO, HI	11-22-83	04-23-84	IB	WA
2) 1982 GAINESVILLE	01-01-82	12-31-82	UF	GA
3) 1981 FLORENCE	01-01-81	09-30-81	FL	SC
4) 1950 ILLINOIS, USA NON-ENSO YEARS	05-01-50	09-30-50	IL	LI
5) 1950 ILLINOIS, USA ENSO YEARS	05-01-50	09-30-50	IL	LI
6) 1950 INDIANA, USA NON-ENSO YEARS	05-01-50	09-30-50	IN	DI
7) 1950 INDIANA, USA ENSO YEARS	05-01-50	09-30-50	IN	DI
8) 1950 IOWA, USA NON-ENSO YEARS	05-01-50	09-30-50	IO	WA
9) 1950 IOWA, USA ENSO YEARS	05-01-50	09-30-50	IO	WA
10) 1950 MINNESOTA NON-ENSO YEARS	05-01-50	09-30-50	MI	NN
11) 1950 MINNESOTA ENSO YEARS	05-01-50	09-30-50	MI	NN
12) 1950 NEBRASKA NON-ENSO YEARS	05-01-50	09-30-50	NE	BR
13) 1950 NEBRASKA ENSO YEARS	05-01-50	09-30-50	NE	BR
14) 1950 MINNnois actual data	05-01-50	09-30-40	MI	NN
15) 1971 MINNESis actual data	05-01-50	09-30-40	MI	NN
16) 1972 MININNois actual data	05-01-50	09-30-40	MI	NN
17) 1973 MINNnois actual data	05-01-50	09-30-40	MI	NN
18) 1974 MINNnois actual data	05-01-50	09-30-40	MI	NN
19) 1975 MINNnois actual data	05-01-50	09-30-40	MI	NN
20) 1976 MINNnois actual data	05-01-50	09-30-40	MI	NN
21) 1977 MINNnois actual data	05-01-50	09-30-40	MI	NN
22) 1978 MINNnois actual data	05-01-50	09-30-40	MI	NN
23) 1979 MINNnois actual data	05-01-50	09-30-40	MI	NN
24) 1980 MINNnois actual data	05-01-50	09-30-40	MI	NN
25) 1981 MINNnois actual data	05-01-50	09-30-40	MI	NN
26) 1982 MINNnois actual data	05-01-50	09-30-40	MI	NN
27) 1983 MINNnois actual data	05-01-50	09-30-40	MI	NN
28) 1984 MINNnois actual data	05-01-50	09-30-40	MI	NN
29) 1985 MINNnois actual data	05-01-50	09-30-40	MI	NN
30) 1986 MINNnois actual data	05-01-50	09-30-40	MI	NN
31) 1987 MINNnois actual data	05-01-50	09-30-40	MI	NN
32) 1988 MINNnois actual data	05-01-50	09-30-40	MI	NN
33) 1989 MINNnois actual data	05-01-50	09-30-40	MI	NN
34) 1970 MINNnois actual data	05-01-50	09-30-40	MI	NN

33 <=== CURRENT WEATHER FILE SELECTION.
 <--- NEW SELECTION?

4

MODIFICATION OF SELECTED MODEL VARIABLES INTERACTIVELY

VARIABLES TO BE MODIFIED

1. Planting Date, Simulation Date and Seeding Depth
2. Plant Population
3. Nitrogen Non-Limiting
4. Irrigation Inputs and Water Balance Switch
5. Fertilizer Inputs
6. Select New Variety
7. Soil Profile Inputs (Water Balance, Root Preference, DMOD)
8. Select Weather Data
9. Initial Soil Fertility and Water,
and Crop Residue Parameters
10. Display Echo
11. End of Changes
12. Abandon all Changes and Return to Experiment Menu

ENTER NUMBER OF MODIFICATION : 31111

```
RUN_ID OUTPUT SUMMARY EXPD_NO: Q1 V MAIN : 1781 TRT_NO: 2
```

LATITUDE = 47.00, SOWING DEPTH = 4. CM, PLANT POPULATION = 7.1 PLANTS/SQ METER
GENETIC SPECIFIC CONSTANTS $P_1 = 120.00$ $P_2 = 625.40$ $P_3 = 10.000$ $P_5 = 685.00$

SOIL PROFILE DATA LOCATION: SWCON= .30 RUNOFF CURVE NO.= 79.0

Press "Enter" to continue

[illegible]

* NOTE: Units are in kg / hectare.

DAY	MONTH	YEAR	INPUTS	KG./HA	DEPTH	SOURCE
-----	-------	------	--------	--------	-------	--------

Press "Enter" to continue

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THE PROGRAM STARTED ON, 125 DAY OF YEAR

[illegible]

Press "Enter" to continue

YIELD (KG/HA)= 3192. (BU/ACRE)=130.4 FINAL GFSH= 2103. KERNEL WT. (mg)=329.2

[illegible]

* NOTE: In the above table, 0.0 represents minimum stress and 1.0 represents maximum stress for water (CSO) and nitrogen (CNSD), respectively.

NOTE: Data modified by the user.
Therefore, the predicted and observed comparison data may not be valid.

SILKING DATE	PREDICTED	OBSERVED
MATURING DATE	200	0
	259	0

Press "Enter" to continue

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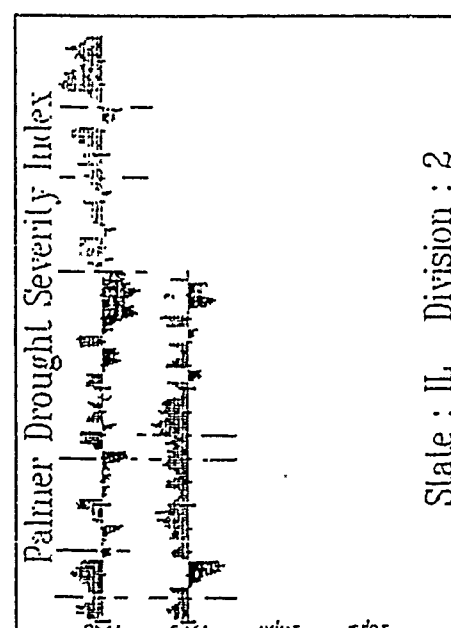
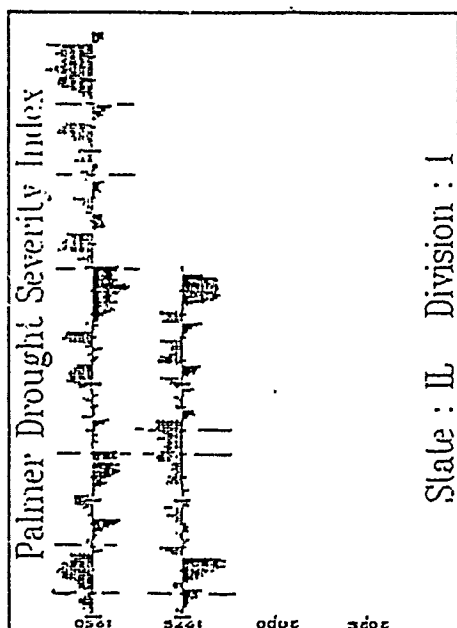
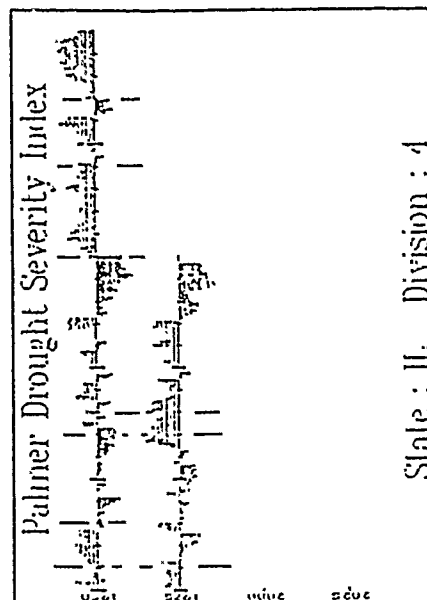
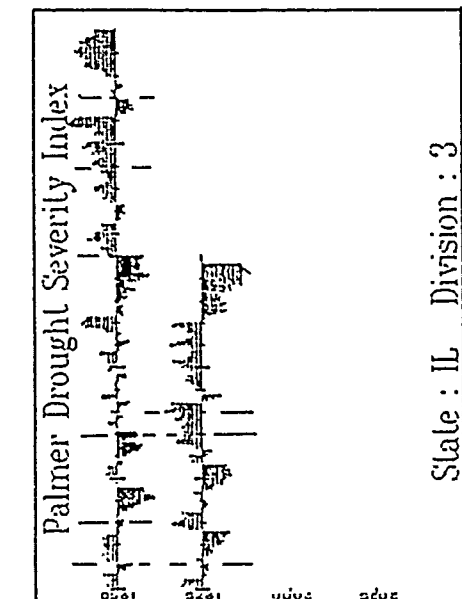
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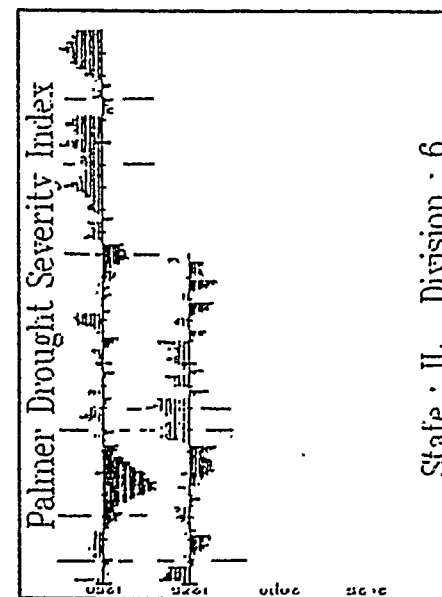
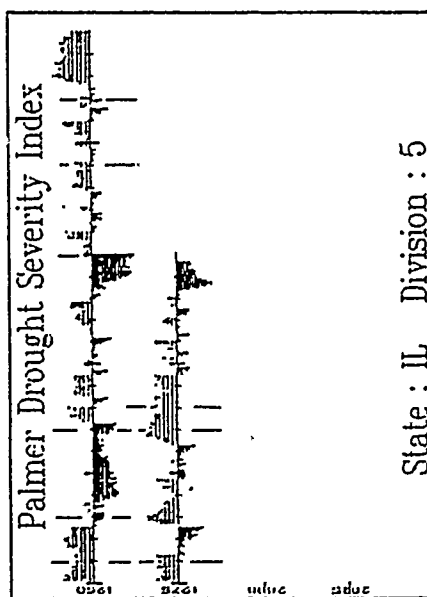
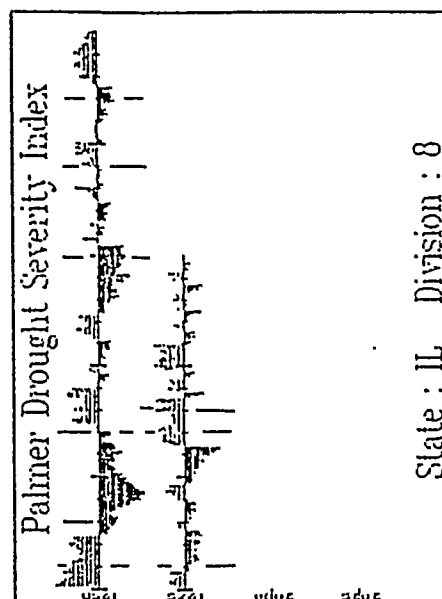
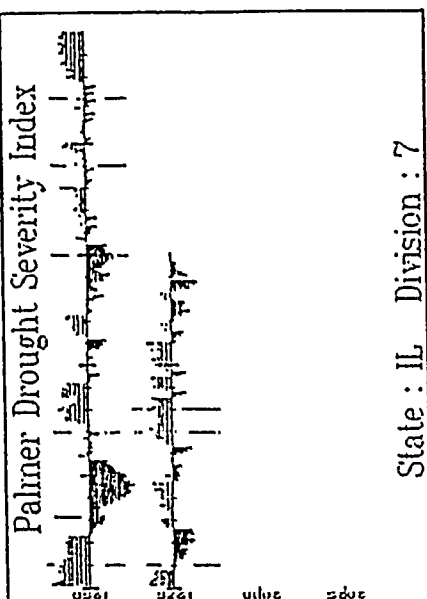
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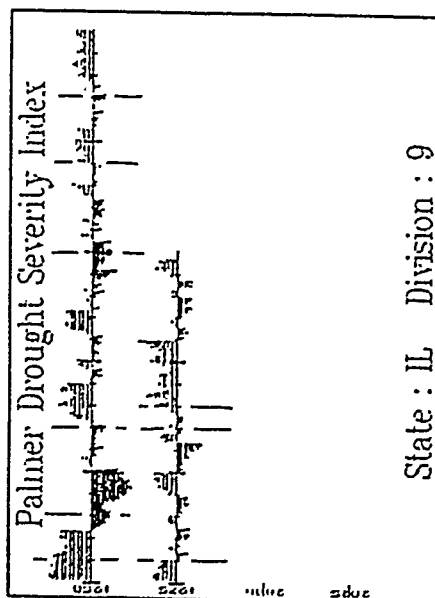
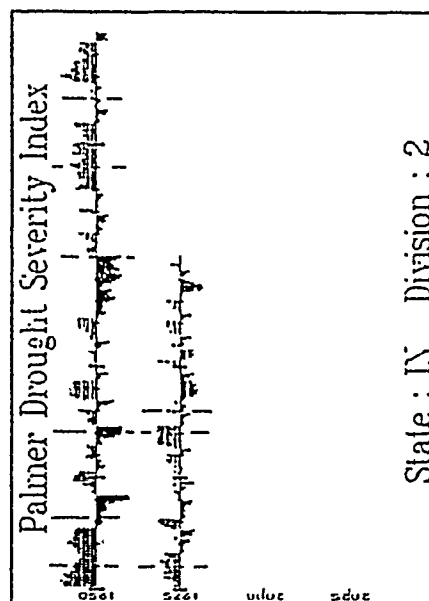
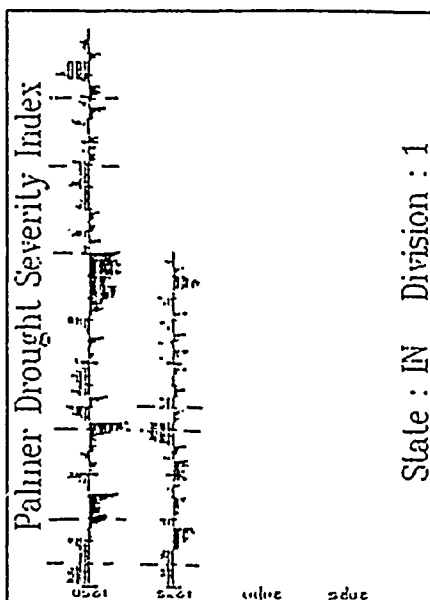
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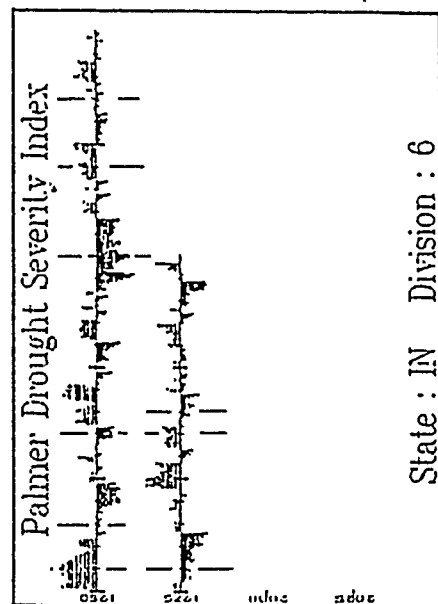
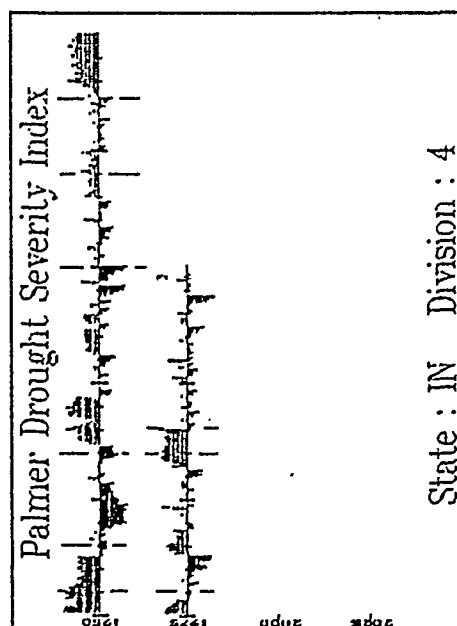
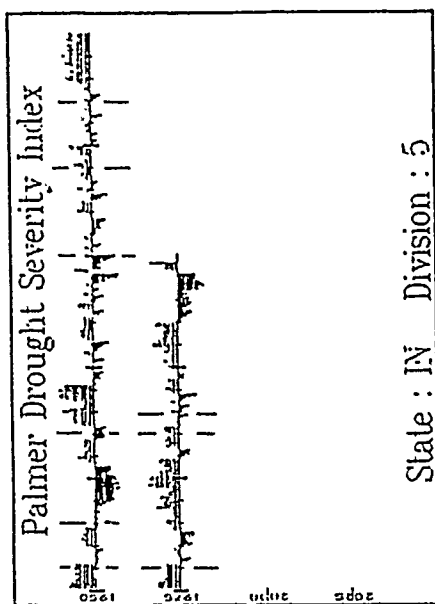
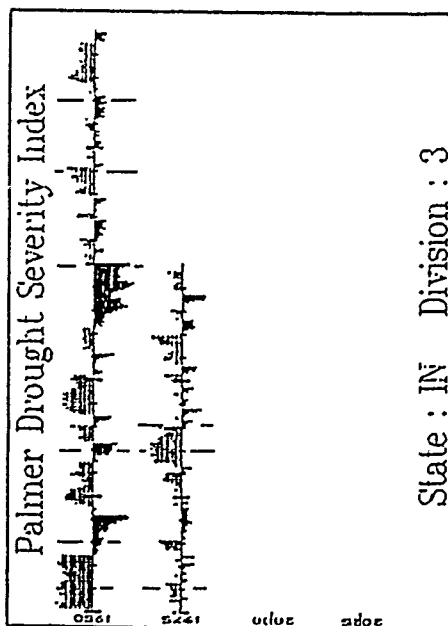
Appendix F. Palmer Drought Severity Index (PDSI):

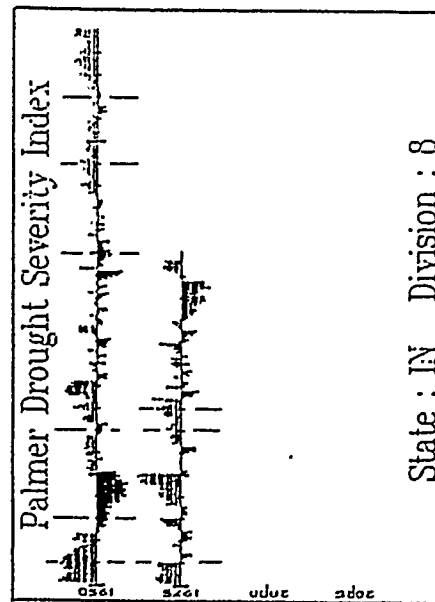
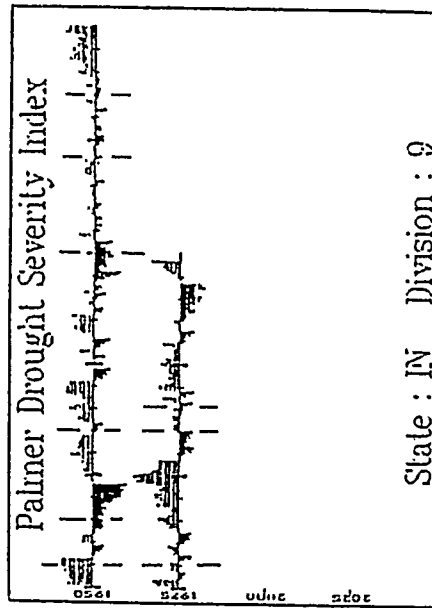
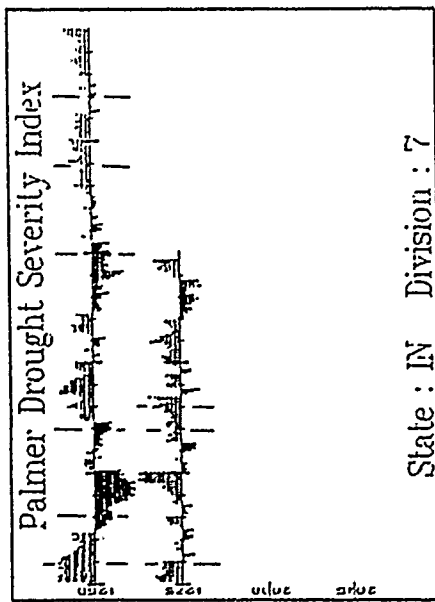
Above the line, the months have moisture surplus, while months below the line are in drought (no units).

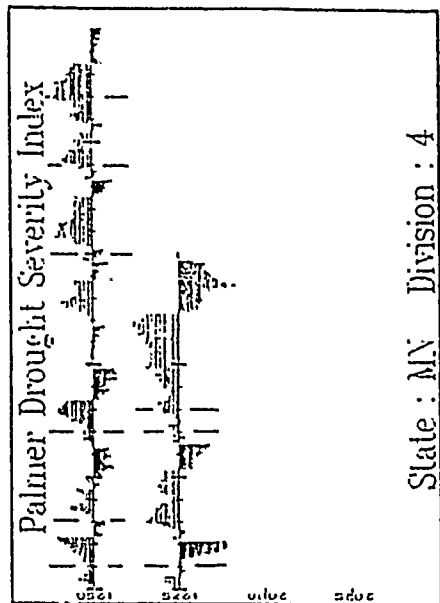
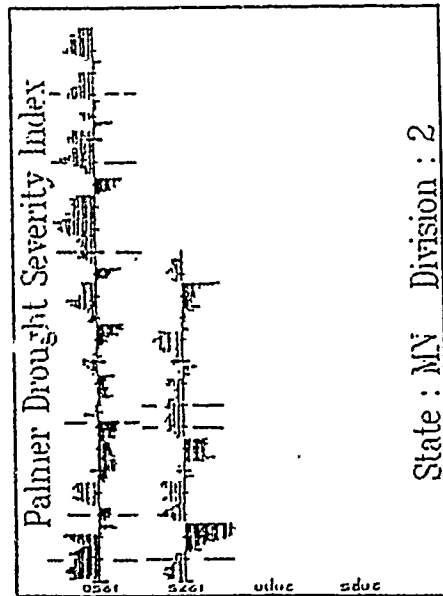
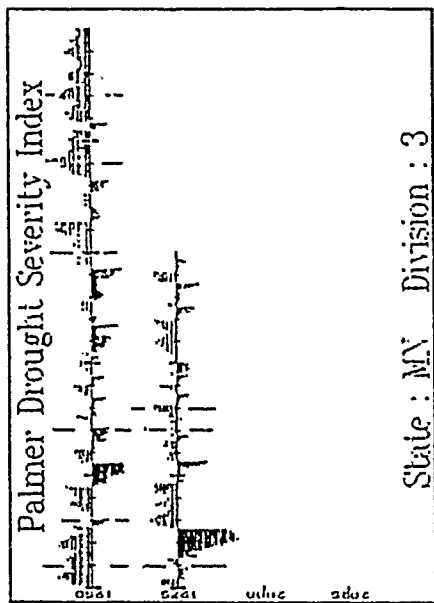
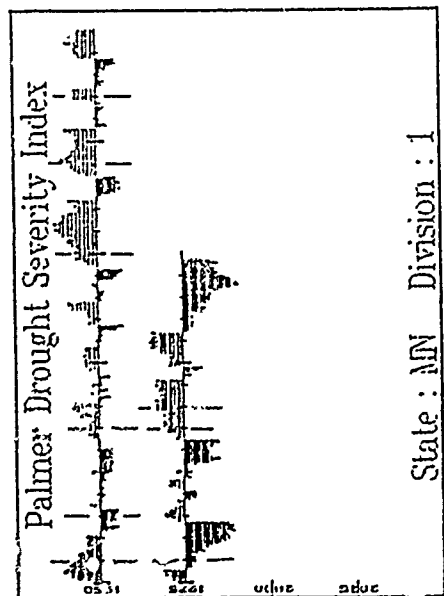


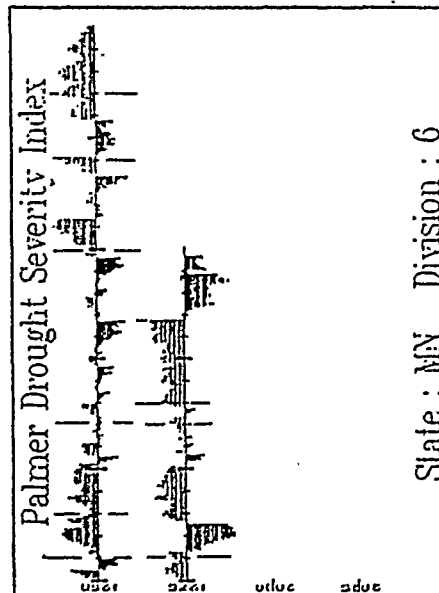
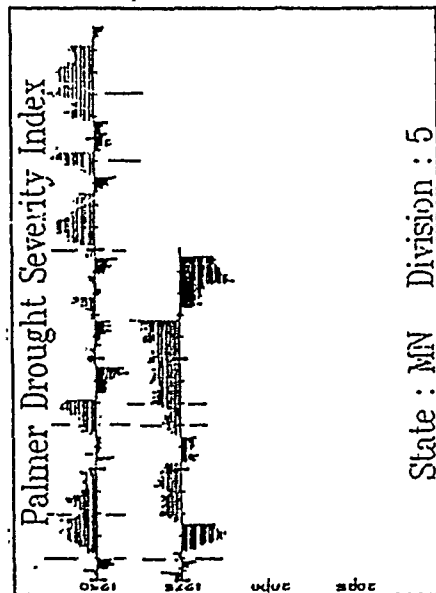
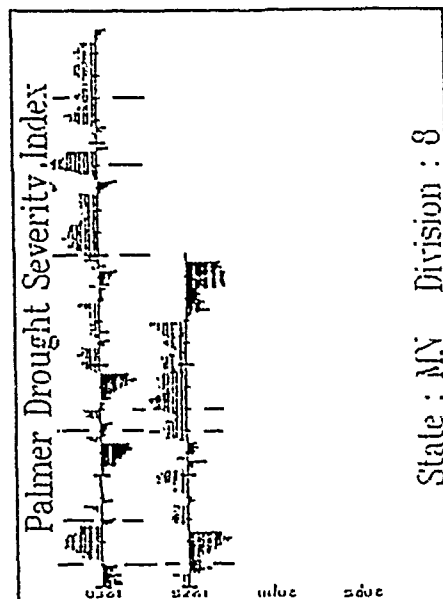


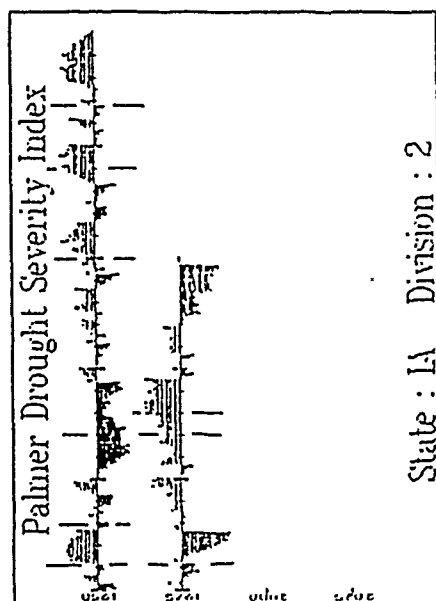
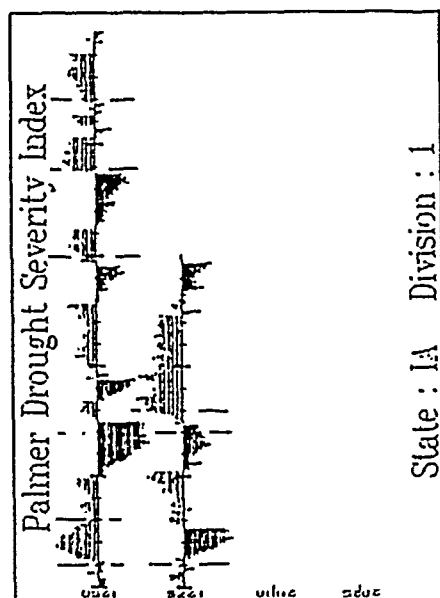
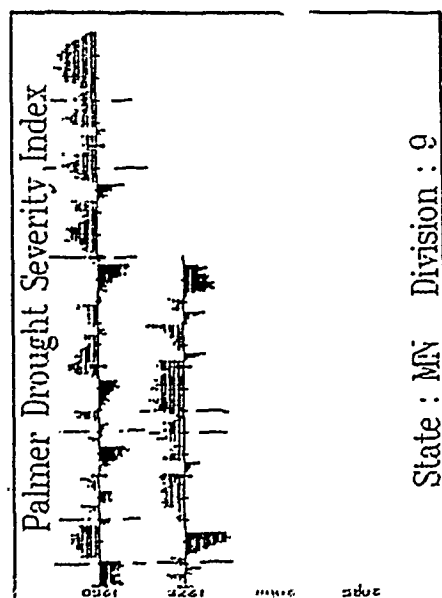


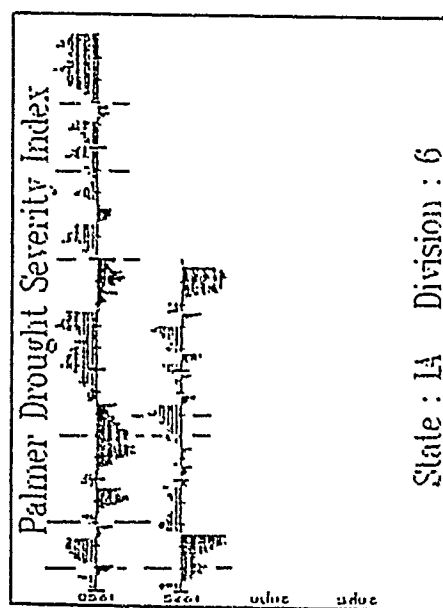
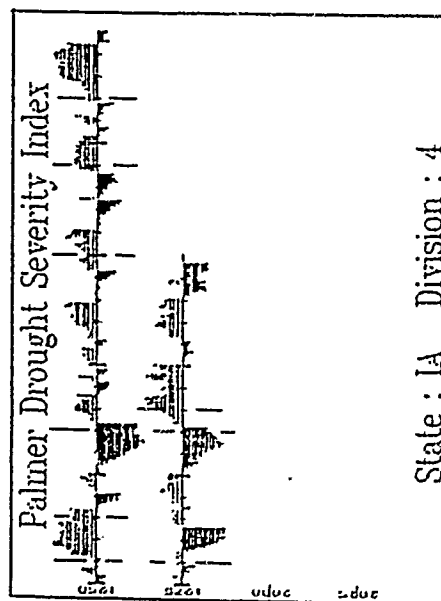
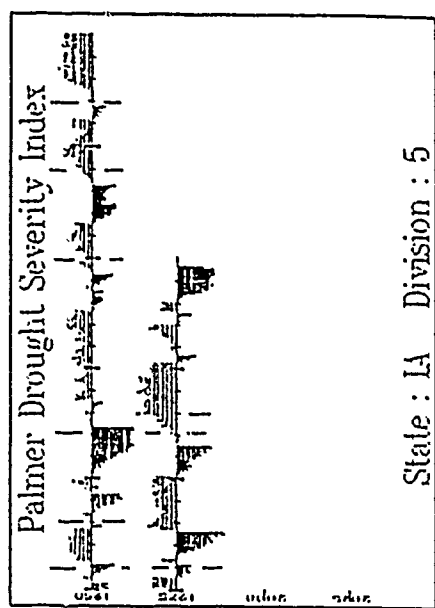
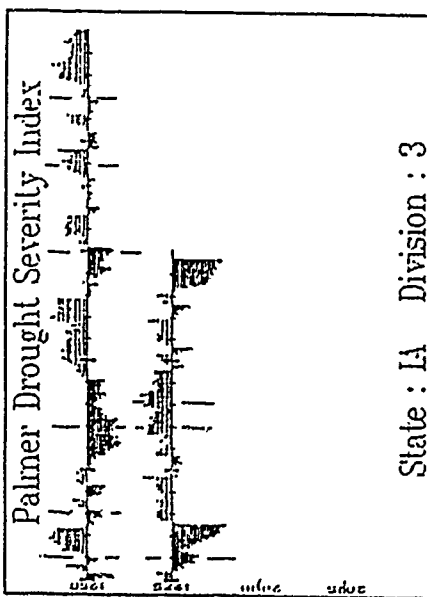


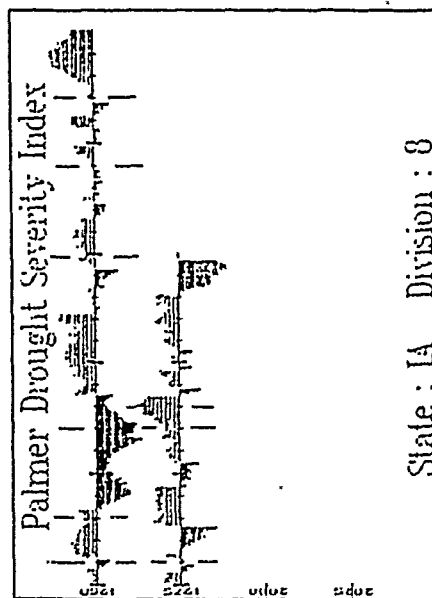
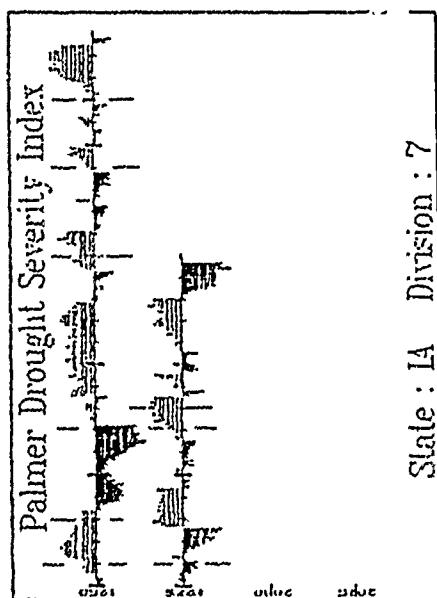
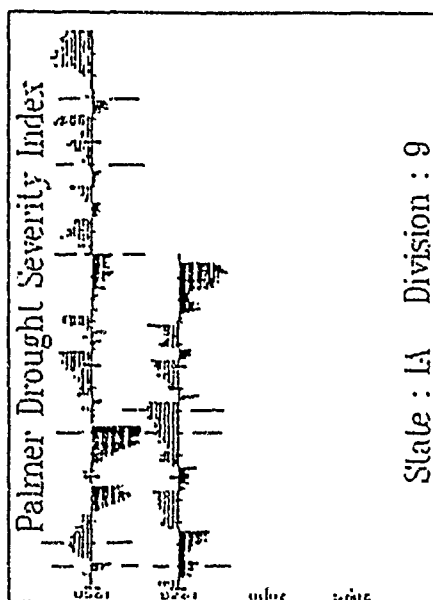


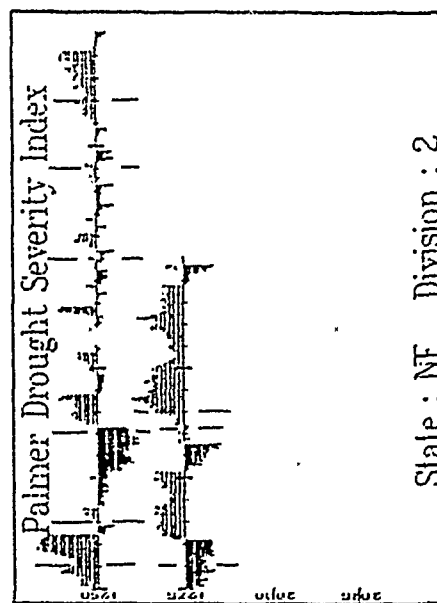
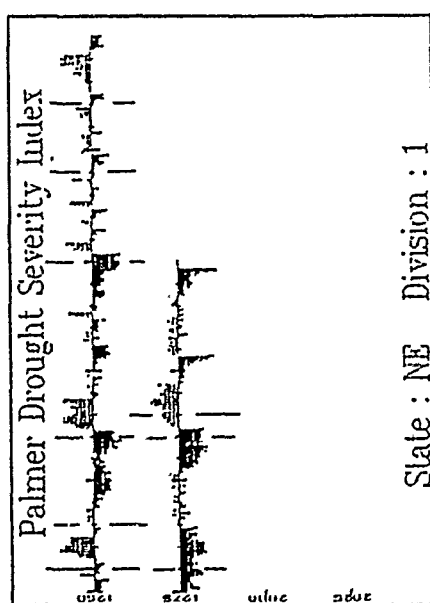
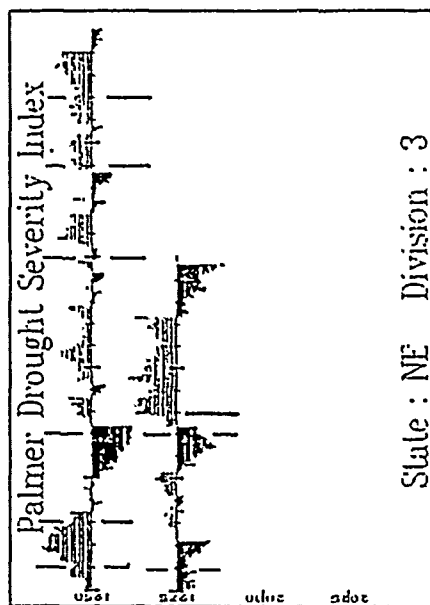


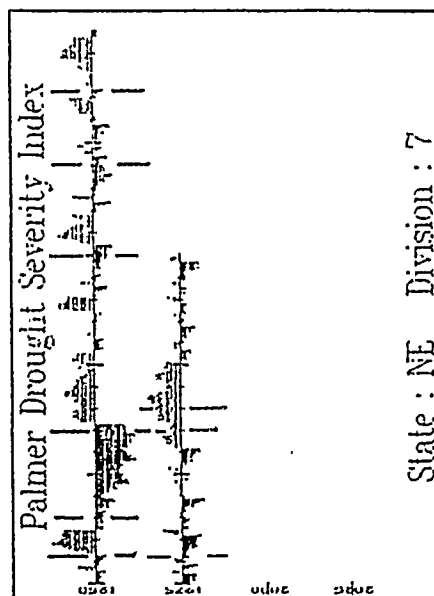
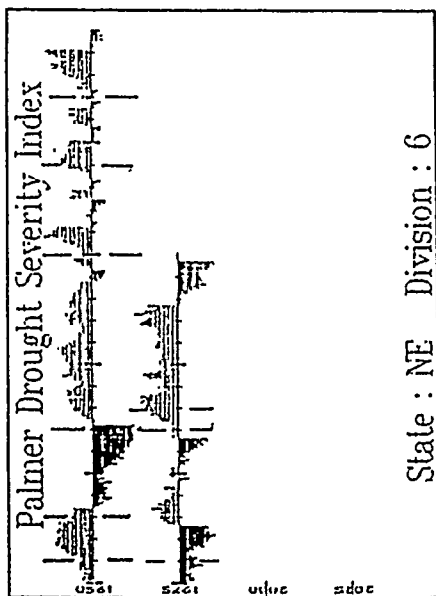
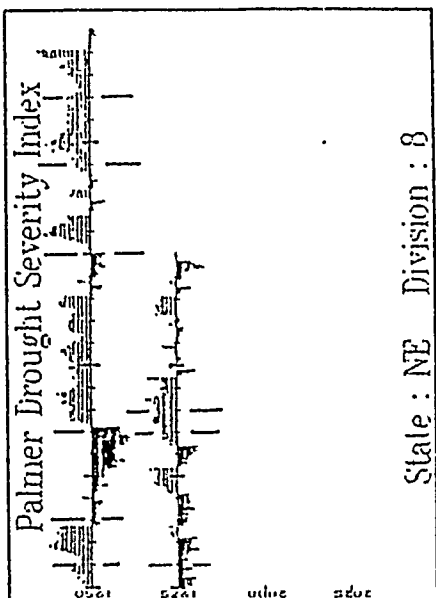












Appendix G. Yearly Corn-Yield
Averages for the U. S. and the
Five Midwestern States.
 (bushels/acre) (USDA-SRS, ANNUAL
 CROP AND LIVESTOCK SUMMARIES)

YEAR	US AVE	IOWA	INDIANA	NEBRASKA	MINNESOTA	ILLINOIS
1950	37.4	47.0	49.5	37.0	38.0	51.0
1951	35.9	43.5	53.0	26.5	39.5	55.0
1952	40.4	64.0	50.0	37.0	50.5	58.0
1953	39.6	53.0	51.5	28.0	48.0	54.0
1954	38.1	52.5	53.5	28.0	50.5	49.5
1955	40.6	48.5	56.0	18.0	49.0	56.0
1956	45.7	51.0	62.0	22.0	57.5	68.0
1957	47.1	62.0	59.0	46.0	56.5	64.0
1958	51.8	65.5	63.0	51.5	54.5	69.0
1959	53.1	65.0	118.4	48.5	49.0	67.0
1960	54.7	62.0	65.7	50.5	52.5	68.0
1961	62.4	75.5	74.0	52.0	64.5	77.0
1962	64.7	76.0	82.0	61.0	59.5	83.0
1963	67.9	81.5	87.0	56.0	67.2	85.0
1964	62.9	77.0	72.0	52.0	53.1	78.0
1965	74.1	82.0	94.0	70.0	61.0	94.0
1966	73.1	89.0	78.0	79.0	76.0	80.0
1967	80.1	88.5	82.0	74.0	72.0	100.0
1968	79.5	93.0	85.0	74.0	81.0	89.0
1969	85.9	98.0	96.0	93.0	85.0	98.0
1970	72.4	86.0	76.0	76.0	85.0	74.0
1971	88.1	102.0	101.0	85.0	83.0	106.0
1972	96.9	116.0	104.0	104.0	93.0	110.0
1973	91.3	107.0	102.0	94.0	93.0	103.0
1974	71.9	80.0	71.0	68.0	61.0	83.0
1975	86.4	90.0	98.0	85.0	70.0	116.0
1976	88.0	91.0	110.0	85.0	59.0	107.0
1977	90.8	86.0	102.0	99.0	100.0	105.0
1978	101.0	115.0	108.0	113.0	104.0	111.0
1979	109.7	127.0	112.0	115.0	100.0	128.0
1980	91.0	110.0	96.0	85.0	97.0	93.0
1981	109.8	127.0	109.0	115.0	110.0	128.0
1982	114.8	121.0	129.0	111.0	113.0	134.0
1983	81.0	87.0	73.0	96.0	84.0	79.0
1984	106.6	112.0	117.0	116.0	107.0	114.0
1985	118.0	126.0	123.0	128.0	115.0	135.0
1986	119.3	135.0	122.0	128.0	122.0	135.0
1987	119.4	130.0	135.0	131.0	127.0	132.0

Appendix H. Yearly Corn-Yield
Averages for the U. S. and the
Five Midwestern States After
a 9-Year Smoothing Technique
 (bushels/acre)

YEAR	US AVG	IOWA	INDIANA	NEBRASKA	MINNESOTA	ILLINOIS
1950	37.6	51.7	51.8	31.5	45.3	53.0
1951	38.0	50.4	52.3	30.2	45.7	52.9
1952	39.9	52.6	54.5	30.4	47.9	56.1
1953	40.4	52.7	54.3	31.6	48.2	56.9
1954	41.8	54.1	55.6	33.7	49.3	58.2
1955	45.6	56.1	56.9	34.9	50.6	60.1
1956	45.7	58.2	58.3	37.6	52.0	61.5
1957	48.1	59.4	61.0	39.3	53.6	63.6
1958	50.9	62.0	64.4	41.9	54.8	66.8
1959	54.2	65.2	68.1	45.1	56.7	70.8
1960	56.7	68.4	69.9	48.8	57.1	73.2
1961	59.9	71.8	73.4	54.2	57.5	76.1
1962	62.7	74.8	75.6	57.8	59.7	77.9
1963	65.9	77.4	77.7	60.3	61.6	81.3
1964	68.8	80.5	80.0	63.2	65.2	83.8
1965	72.3	84.5	83.3	67.9	68.8	87.1
1966	73.4	85.6	83.6	70.6	71.1	86.8
1967	76.0	88.5	85.7	73.2	73.7	89.3
1968	79.2	92.4	87.6	78.6	76.6	92.1
1969	82.4	95.7	90.9	83.2	81.0	94.9
1970	82.1	96.6	88.3	83.0	81.0	93.7
1971	83.6	95.6	90.6	83.7	80.3	97.7
1972	84.5	95.8	93.7	84.9	78.9	98.4
1973	85.7	95.0	95.6	87.7	81.0	100.2
1974	87.4	97.0	96.9	89.9	83.1	101.7
1975	91.6	101.5	100.8	94.2	84.8	107.7
1976	91.9	102.4	100.3	94.2	86.3	106.2
1977	93.3	103.6	100.8	95.4	88.2	108.2
1978	95.9	105.2	103.8	97.3	90.4	111.7
1979	96.9	106.0	104.1	100.4	93.0	111.2
1980	100.6	108.4	106.2	103.9	97.1	111.0
1981	102.7	112.3	107.6	108.7	103.3	114.1
1982	105.7	117.7	109.9	111.9	105.8	117.4
1983	107.7	119.4	112.9	113.9	108.5	119.8
1984	112.0	122.6	118.3	120.4	114.1	124.9
1985	113.4	123.4	120.6	124.1	116.2	125.4
1986	119.1	130.8	128.0	129.3	122.7	133.7
1987	119.4	132.2	129.2	129.7	124.8	132.9

Appendix I. Bibliography

Andresen, J.A., R.F. Dale, J.J. Flechter, and P.V. Preckel. 1987. Prediction of corn yields using an energy-crop growth index for counties in Indiana. pp. 231-233. In Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology, W. Lafayette, IN. 15-18 September 1987.

Angell, J.K., and J. Korshover. 1978. Estimate of global temperature variations in the 100-30 mb layer between 1958 and 1977. Mon. Wea. Rev. 106:1422-1432.

Berlage, H.P. 1961. Variations in the general atmospheric and hydrospheric circulation of periods of a few years duration affected by variations of solar activity. Ann. New York Acad. Sci. 95:354-367.

Berlage, H.P. 1966. The Southern Oscillation and world weather. K. N. d. Meteorol. Inst. Meded. Verh. 88:1-152.

Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. Mon. Wea. Rev. 97:163-172.

Cane, M., and S. Zebiak. 1986. El Nino prediction from Columbia University scientists. Bull. Amer. Meteor. Soc. 67:580-581.

Carlson, J.D., and S.H. Gage. 1987. Quantitative relationships between crop phenology, insect pest phenology, and temperature for field corn in Michigan. pp. 259-262. In Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology, W. Lafayette, IN. 15-18 September 1987.

Changnon, S.A., S. Hollinger, and P. Garcia. 1989. Analyzing the effects of additional rainfall on corn and soybean yields. pp. 41-45. In Proc. from the 19th Conf. Agric. and Forest Meteor. and 9th Conf. Biometeor. and Aerobiology, Charleston, SC. 7-10 March 1989.

Chavez, F. 1987. The annual cycle of SST along the Peru coast. Trop. Ocean-Atmos. Newslett. 37:4-6.

Chiu, W., and A. Lo. 1979. A preliminary study of the possible statistical relationship between the tropical Pacific sea surface temperature and the atmospheric circulation. Mon. Wea. Rev. 107:18-25.

Chu, P.-S., and R.W. Katz. 1987. Measures of predictability with applications to the Southern Oscillation. Mon. Wea. Rev. 115:1542-1549.

Craig, A.K., and I. Shimada. 1986. El Nino flood deposits at Batan Grande, Northern Peru. *Geoarchaeology* 1:29-38.

Dale, R.F., and R.H. Shaw. 1965. The climatology of soil moisture, atmospheric evaporative demand, and resulting moisture stress days for corn at Ames, Iowa. *J. Appl. Meteor.* 4:661-669.

DeVries, T.J. 1986. Fossil evidence for an early Pleistocene origin of El Nino off Peru. pp. 27-31. In *Proc. of the Chapman Conf. on El Nino, Guayaquil, Ecuador. 22-29 October 1986.*

Dickson, R.R., and J. Namias. 1976. North American influences on the circulation and climate of the North Atlantic sector. *Mon. Wea. Rev.* 104:1255-1265.

Douglas, A.V., D.R. Cayan, and J. Namias. 1982. Large-scale changes in North Pacific and North American weather patterns in recent decades. *Mon. Wea. Rev.* 110:1851-1862.

Duchon, C.E. 1986. Corn yield prediction using climatology. *J. Climate Appl. Meteor.* 25:581-590.

Flueck, J.A., and T.J. Brown. 1987. A new approach to identification and prediction of "El Nino" events. *Trop. Ocean-Atmos. Newslett.* 37:2-4.

Folland, C.K., D.E. Parker, and F.E. Kates. 1984. Worldwide marine temperature fluctuations 1856-1981. *Nature* 310:670-673.

Fraedrich, K. 1988. El Nino/Southern Oscillation predictability. *Mon. Wea. Rev.* 116:1001-1012.

Fu, C., H.F. Diaz, and J.O. Fletcher. 1986. Characteristics of the response of sea surface temperatures in the central Pacific associated with warm episodes of the Southern Oscillation. *Mon. Wea. Rev.* 114:1716-1738.

Gallo, K.P., and T.K. Flesch. 1987. Crop development in the U. S. corn belt monitored with the NOAA AVHRR. pp 101-102. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeo. and Aerobiology, W. Lafayette, IN. 15-18 September 1987.*

Garcia, P., S.E. Offutt, M. Pinar, and S.A. Changnon. 1987. Corn yield: Effects of technological advance and weather conditions. *J. Climate Appl. Meteor.* 26:1092-1102.

Graham, N.E., and W.B. White. 1988. The El Nino cycle: A natural oscillator of the Pacific Ocean-atmosphere system. *Science* 240:1293-1302.

Handler, P. 1984. Possible association of stratospheric aerosols and El Nino type events. *Geophys. Res. Lett.* 11: 1121-1124.

Handler, P., and B. O'Neill. 1987. Volcanic aerosols, El Nino events, Indian monsoons, tropical cyclones and U. S. corn yields. pp. 512-515. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Conf. Biometeor. and Aerobiology*, W. Lafayette, IN. 15-18 September 1987.

Harnack, R.P. 1979. A further assessment of winter temperature predictions using objective methods. *Mon. Wea. Rev.* 107:250-267.

Hayes, J.T., P.A. O'Rourke, W.H. Terjung, and P.E. Todhunter. 1982. A feasible crop yield model for worldwide international food production. *Int. J. Biometeor.* 26:239-257.

Hollinger, S.E., and J.W. Mjelde. 1987. Development of crop weather indices. pp. 168-171. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Confer. Biometeor. and Aerobiology*, W. Lafayette, IN. 15-18 September 1987.

Hollinger, S.E. 1989. Modeling the effects of weather and management practices on maize yield. *Agric. For. Meteor.* 44:81-97.

Horel, J.D., and J.M. Wallace. 1981. Planetary-scale atmospheric phenomena associated with the Southern Oscillation. *Mon. Wea. Rev.* 109:813-829.

Horel, J.D., V.E. Kousky, and M.T. Kagano. 1986. Atmospheric conditions in the Atlantic sector during 1983 and 1984. *Nature* 322:248-251.

Inoue, M., and J.J. O'Brien. 1986. Predictability of the decay of the 1982/1983 El Nino. *Mon. Wea. Rev.* 114:967-972.

Iwasaki, T., and I. Hirota. 1988. The influence of the Southern Oscillation on extratropical circulations during the Northern hemisphere winter. *J. Met. Soc. Japan* 66:419-432.

Jensen, M.E. 1973. *Consumptive use of water and irrigation water requirements*. 1st ed. American Society of Engineers, N. Y., N. Y.

Jones, C.A., and J.R. Kiniry. 1986. *CERES-Maize: A simulation model of maize growth and development*. 1st ed. Texas A&M Press, College Station, TX.

Jones, P.D., T.M.L. Wigley, and P.M. Kelly. 1982. Variations in surface air temperatures: Part I. Northern hemisphere, 1881-1980. *Mon. Wea. Rev.* 110:59-70.

Julian, P.R., and R.M. Chervin. 1978. A study of the Southern Oscillation and Walker circulation phenomenon. *Mon. Wea. Rev.* 106:1433-1451.

Kogan, F.N. 1987. Evolution of weather impact on yield variability. pp. 239-240. In *Proc. from the 18th Conf. Agric. and Forest Meteor. and 8th Confer. Biometeor. and Aerobiology*, W. Lafayette, IN. 15-18 September 1987.

La Cock, G.D. 1986. The Southern Oscillation, environmental anomalies, and mortality of two Southern African seabirds. *Climatic Change* 8:173-184.

Lau, K.M., and P.H. Chan. 1986. The 40-50 day oscillation and the El Nino/Southern Oscillation: A new perspective. *Bull. Amer. Meteor. Soc.* 67:533-534.

Liverman, D.M., W.H. Terjung, J.T. Hayes, and L.O. Mearns. 1986. Climatic change and grain corn yields in the North American Great Plains. *Climatic Change* 9:327-347.

Lussky, G.R. 1989. Current issues relating to the El Nino/Southern Oscillation. *Nat. Wea. Dig.* 14:26-31.

Madden, R.A., and D.J. Shea. 1978. Estimates of the natural variability of time-averaged temperatures over the United States. *Mon. Wea. Rev.* 106:1695-1703.

Meyer, S.J., K.G. Hubbard, and D.A. Wilhite. 1989. Developing a crop specific drought index for corn: A preliminary report. p. 75. In *Proc. from the 19th Conf. Agric. and Forest Meteor. and 9th Confer. Biometeor. and Aerobiology*, Charleston, SC. 7-10 March 1989.

Mjelde, J.W., and S.E. Hollinger. 1989. Climate indices for application in empirical crop production studies. *Agric. Sys.* 30:1-14.

Muchow, R.C., T.R. Sinclair, and J.M. Bennett. 1990. Temperature and solar radiation effects on potential maize yield across locations. *Agron. J.* 82:338-343.

Namias, J. 1963. Interactions of circulation and weather between hemispheres. *Mon. Wea. Rev.* 91:482-486.

Namias, J. 1969. Seasonal interaction between the North Pacific ocean and the atmosphere during the 1960's. *Mon. Wea. Rev.* 97:173-192.

Nelson, W.L., and C.R. Eklund. 1985. Minimizing risks in the commodity industry through use of computer-based crop models. pp. 177-179. In Proc. of the 17th Conf. Agric. and Forest Meteor. and 7th Conf. Biometeor. and Aerobiology, Scottsdale, AZ. 21-24 May 1985.

Newman, J.E., and K.L. Scheeringa. 1985. Seasonal weather impacts on Indiana corn fields, 1980-1984. pp. 270-280. In Proc. of the 17th Conf. Agric. and Forest Meteor. and 7th Conf. Biometeor. and Aerobiology, Scottsdale, AZ. 21-24 May 1985.

Nicholls, N. 1989. How old is ENSO? Climatic Change 14: 111-115.

Olson, K.R., and G.W. Olson. 1985. A soil-climate index to predict corn yield. Agric. Sys. 18:227-237.

Owen, J.A., and T.N. Palmer. 1987. The impact of El Nino on an ensemble of extended-range forecasts. Mon. Wea. Rev. 115:2103-2117.

Parker, D.E. 1983. Documentation of a Southern Oscillation index. Met. Mag. 112:184-187.

Philander, S.G.H., T. Yamagata, and R.C. Pacanowski. 1984. Unstable air-sea interactions in the Tropics. J. Atmos. Sci. 41:604-613.

Philander, S.G.H. 1990. El Nino, La Nina, and the Southern Oscillation. 1st ed. Academic Press, Inc., San Diego, CA.

Quinn, W.H., and W.V. Burt. 1972. Use of the Southern Oscillation in weather prediction. J. Appl. Meteor. 11:616-628.

Quinn, W.H., D.O. Zopf, K.S. Short, and R.T.W.K. Yang. 1978. Historical trends and statistics of the Southern Oscillation, El Nino, and Indonesian droughts. Fish. Bull. 76:663-678.

Ramage, C.S. 1975. Preliminary discussion of the meteorology of the 1972-73 El Nino. Bull. Amer. Meteor. Soc. 56:234-242.

Rasmusson, E.M., and T.H. Carpenter. 1982. Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Nino. Mon. Wea. Rev. 110:354-384.

Rasmusson, E.M., and T.H. Carpenter. 1983. The relationship between Eastern Equatorial Pacific sea surface temperatures over India and Sri Lanka. Mon. Wea. Rev. 111:517-528.

Rasmusson, E.M., and J.M. Wallace. 1983. Meteorological aspects of the El Nino/Southern Oscillation. *Science* 222: 1195-1202.

Reynolds, R.W. 1983. A comparison of sea surface temperature climatologies. *J. Appl. Meteor.* 22:447-459.

Rogers, J.C. 1987. Variability in clouds and precipitation over South America and the tropical Atlantic associated with the Southern Oscillation. *Trop. Ocean-Atmos. Newslett.* 37: 7-10.

Ropelewski, C.F., and M.S. Halpert. 1986. North American precipitation and temperature patterns associated with the El Nino/Southern Oscillation (ENSO). *Mon. Wea. Rev.* 114: 2352-2362.

Ropelewski, C.F., and M.S. Halpert. 1987. Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation. *Mon. Wea. Rev.* 115:1606-1626.

Rosenzweig, C. 1989. Climate change and CO₂ effects on wheat and corn in the Great Plains. pp. 26-29. In *Proc. from the 19th Conf. Agric. and Forest Meteor. and 9th Conf. Biometeor. and Aerobiology*, Charleston, SC. 7-10 March 1989.

Runge, E.C.A. 1968. Effects of rainfall and temperature interactions during the growing season on corn yield. *Agron. J.* 60:503-507.

Sandweiss, D.H. 1986. The beach ridges at Santa, Peru: El Nino, uplift, and prehistory. *Geoarchaeology* 1:17-28.

Schopf, P.S., and M.J. Suarez. 1988. Vacillations in a coupled ocean-atmosphere model. *J. Atmos. Sci.* 45:549-567.

Schneider, D., and D.C. Duffy. 1988. Historical variation in guano production from the Peruvian and Benguela upwelling ecosystems. *Climatic Change* 13:309-316.

Schreiber, R.W., and E.A. Schreiber. 1987. Equatorial seabirds and El Nino: Close encounters in a marine system. *Trop. Ocean-Atmos. Newslett.* 37:14-15.

Shaw, L.H. 1964. The effect of weather on agricultural output: A look at methodology. *J. Farm Econ.* 46:218-230.

Shaw, R.H. 1963. Estimation of soil moisture under corn. Research bulletin 520. Agricultural and Home Economics Experiment Station, Iowa State University.

Shaw, R.H. 1974. A weighted moisture-stress index for corn in Iowa. *Iowa St. J. of Research.* 49:101-114.

Shaw, R.H. 1977. Use of a moisture-stress index for examining climate trends and corn yields in Iowa. Iowa St. J. of Research. 51:249-254.

Shaw, R.H. 1983. Soil moisture and moisture stress prediction for corn in a western corn belt state. Korean J. Crop Sci. 28:1-11.

Singh, U. 1985. A crop growth model for predicting corn (Zea mays L.) performance in the tropics. Ph.D. diss. University of Hawaii, Honolulu.

Skaggs, R.H., and D.G. Baker. 1985. Fluctuations in the length of the growing season in Minnesota. Climatic Change 7:403-414.

Sonka, S.T., P.J. Lamb, S. Hollinger, and J. Mjelde. 1985. The economic use of weather and climate information: Theory and an agricultural example. pp. 194-195. In Proc. from the 17th Conf. Agric. and Forest Meteor. and 7th Conf. Biometeor. and Aerobiology, Scottsdale, AZ. 21-24 May 1985.

Sonka, S.T., J.W. Mjelde, P.J. Lamb, S.E. Hollinger, and B.L. Dixon. 1987. Valuing climate forecast information. J. Climate Appl. Meteor. 26:1080-1091.

Stallings, J.L. 1961. A measure of the influence of weather on crop production. J. Farm Econ. 43:1153-1160.

Suarez, M.J., and P.S. Schopf. 1988. A delayed action oscillator for ENSO. J. Atmos. Sci. 45:3283-3287.

Terjung, W.H., D.M. Liverman, J.T. Hayes, and collaborators. 1984. Climatic change and water requirements for grain corn in the North American Great Plains. Climatic Change 6:193-220.

Terjung, W.H., J.T. Hayes, P.A. O'Rourke, and P.E. Todhunter. 1984. Yield responses of crops to changes in environment and management practices: Model sensitivity analysis. I. Maize. Int. J. Biometeor. 28:261-278.

Thompson, L.G., and E. Mosley-Thompson. 1986. Assessment of 1500 years of climate variability and potential of long term record of ENSO events from Andean glaciers. pp. 112-114. In Proc. of the Chapman Conf. on El Nino, Guayaquil, Ecuador. 27-31 October 1986.

van Loon, H., and R.A. Madden. 1981. The Southern Oscillation. Part I: Global associations with pressure and temperature in northern winter. Mon. Wea. Rev. 109:1150-1162.

van Loon, H., and K. Labitzke. 1987. The Southern Oscillation. Part V: The anomalies in the lower stratosphere of the northern hemisphere in winter and a comparison with the quasi-biennial oscillation. *Mon. Wea. Rev.* 115:357-369.

Walker, G.T. 1924. Correlation in seasonal variations of weather, IX: A further study of world weather. *Memoirs of the India Meteorological Department* 24(9):275-332.

Weare, B.C. 1986. An extension of an El Nino index. *Mon. Wea. Rev.* 114:644-647.

Wells, L.E. 1986. An alluvial record of El Nino events from Northern coastal Peru. pp. 68-69. In *Proc. from the Chapman Conf. on El Nino, Guayaquil, Ecuador. 27-31 October 1986.*

Wooster, W.S., and O. Guillen. 1974. Characteristics of El Nino in 1972. *J. Mar. Res.* 32:378-404.

Yasunari, T. 1987. Global structure of the El Nino/Southern Oscillation. Part I. El Nino composites. *J. Met. Soc. Japan* 65:67-80.

Yasunari, T. 1987. Global structure of the El Nino/Southern Oscillation. Part II. Time Evolution. *J. Met. Soc. Japan* 65:81-102.

Zebiak, S.E., and M.A. Cane. 1987. A model El Nino-Southern Oscillation. *Mon. Wea. Rev.* 115:2262-2278.